学位申請論文

A study on the formation of the identity-difference concept by Japanese monkeys using a small number of color stimuli.

（少数の色刺激を用いたニホンザルの同異概念の形成に関する一研究）

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論文内容の要旨

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（論文題目）

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一般に，〝同異〟概念の形成には，多種類の刺激を2個ずつ用意してその中からランダムに2個の組み合せがつくられた場合に，それらの2個の刺激が同じ場合と異なる場合とを弁別することが必要であるといわれる。しかし，最少2種類の刺激があれば，この〝同じ〟あるいは〝異なる〟という刺激間の関係を見出すことは可能である。このように最小限の刺激から〝同異〟の概念を抽象する能力がヒト以外の霊長類にもあるか否かは類人猿についてすら未だ明らかではない。申請論文は，ニホンザルにおいてこの少数刺激からの同異概念の形成が可能であるという新しい事実を示し，更にその成立を促進させる要因の分析をすすめた。

実験1では，〝同異〟の関係を抽象するために必要最小限の2個の色刺激，たとえば赤と紫を用いて，4頭のニホンザルに，〝同じ〟刺激対が呈示された時のみレバーを押すことを訓練した。すなわち同じ色が示されて

いる間の反応は変動間隔スケジュールによって強化されるが，違う色が示されている間のレバー押し反応は消去された。この〝同異〟の弁別学習を完成後，訓練に用いられなかった新しい2色，たとえば青と青緑が示された場合，4頭のうち3頭のサルは，訓練時と同様に同じ刺激対に対してより高頻度のレバー押し反応を続け，2種類の刺激から同異の関係概念を獲得したことを示した。

実験1において同異概念の学習を成功させた要因として，次の2点が考えられる。第1は，〝同じ〟刺激対と〝異なる〟刺激対に対して，それぞれレバーを押すあるいは押さないという別個の反応を要求したこと，第2に試行内に変動間隔による強化スケジュールを採用したことであった。これらの要因を分析するために，まず実験2において，同じ刺激に対し右レバー，異なる刺激に対して左レバーを押すことがそれぞれ強化される継時弁別が訓練された結果，この学習は新しい色刺激へ転移しなかった。すなわち，別個の反応を形成するという第1の要因は否定された。次に実験3では，見本合せ場面における学習の転移が，試行毎に1回の反応を要求する従来の手続きと変動間隔スケジュールを用いる新しい手続きとの間で比較された結果，3頭のサルのすべてが，後者の条件でより多くの転移を示した。

以上三つの実験結果から，1）ニホンザルは必要最小限の2種類の刺激から〝同異〟の概念を形成することができる，2）この概念形成を可能にした決定的要因は，試行内に用いられた変動間隔スケジュールである，ことが明らかにされた。

A study on the formation of the identity-difference concept by Japanese monkeys using a small number of color stimuli.

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ABSTRACT

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Japanese monkeys were trained to form the identity-difference concept. In Experiment 1, four monkeys were trained with two colors to discriminate matching stimulus pairs from non-matching pairs by only reinforcing lever-pressing responses to matching pairs with a variable-interval schedule. Three monkeys showed successful transfer of this discrimination to two new colors, thus demonstrating that some Japanese monkeys are able to form this relational concept from a minimum number of stimuli. In Experiment 2, two monkeys were trained in a Yes/No procedure with three colors to press one lever under matching pairs and another lever under non-matching pairs. Poor transfer performances to three new colors suggested that simultaneously establishing two different responses to matching and non-matching pairs is ineffective in forming the concept. In Experiment 3, the amount of transfer to three new colors after mastering a standard three-color matching-to-sample task was compared with that of a modified task in which correct responses were reinforced with a variable-interval schedule. All three monkeys showed greater transfer with the modified procedure. It was concluded that an intermittent-reinforcement schedule adopted

within trials is effective in forming the identity-difference concept.

Key words: concept formation, relational concept, identity-difference concept, matching-to-sample, conditional discrimination, abstraction, key press, lever press, monkeys.

The formation of the identity-difference concept by an animal can be objectively shown by the fact that the general relation of identity or difference of stimuli comes to control the animal's behavior as a discriminative stimulus. The experimental demonstration of the evidence for this relational control demands not only accurate performance in a task incorporating identity-difference judgment with regard to several stimuli, but also successful transfer of that performance to new stimuli which were not used in the original task. Previous work on oddity learning set demonstrated that monkeys are able to form this relational concept (Levine & Harlow, 1959; Shaffer, 1967; Thomas & Boyd, 1973; Thomas & Kerr, 1976).[2] These studies suggest that the identity-difference relation of stimuli comes to control the monkeys' behaviors if the animals are trained with a great number of instances which have a common aspect based on identity-difference.

However, the identity-difference relation can be easily abstracted, at least by humans, from a set of instances constructed with a minimum number of stimuli (e.g. AA, BB, AB, and BA.). Premack (1978) proposed that the animal's behavior is more or less concurrently controlled by two factors: the absolute values of the stimuli, and the general relations of the stimuli. As he suggested, species differences in the ability for abstraction can be measured by the tendencies of the relational and absolute (or stimulus-specific) aspects of stimuli to control the animal's operant behavior. From this point of view, comparative studies on the ability for abstraction in animals may not

need to use a large number of instances of stimuli. Rather, it is more important to examine which aspects of the stimuli -- that is, general relations of stimuli or specific aspects of the stimuli -- are apt to control the animal's behavior when a small number of stimuli are used for establishing conceptual behavior. In other words, the important question is: how abstract is the animal's apparently conceptual behavior?

Fujita (Note 2, 3) investigated this problem using a matching-to-sample procedure with two colors. He examined the transfer of matching-to-sample discriminations of Japanese monkeys to new colors without differential reinforcement, and concluded that their two-color matching-to-sample behaviors are only weakly controlled by the general relation of identity-difference between stimuli, and mainly controlled by the specific relation between the sample and the correct comparison stimulus. This finding suggests the fact that the identity-difference relation of stimuli controls the monkey's behavior with difficulty when a set of instances constructed with a minimum number of stimuli is used. But several studies with pigeons as subjects which employed slightly modified procedures for matching-to-sample showed somewhat strong stimulus control by identity-difference, although a relatively small number of stimuli were used (Honig, 1965; Malott & Malott, 1970; Malott, Malott, Svinicki, Kladder, & Ponicki, 1971; Urcuioli, 1977; Urcuioli & Nevin, 1975; Zentall & Hogan, 1978). Considering the fact that Holmes (1979) and Carter and Taten (Note 1) failed to demonstrate concept learning in standard

matching-to-sample procedures with numerous stimuli, some independent variables other than the number of stimuli should play an important role for establishing relatively strong stimulus control by identity-difference. Thus, it is still possible for monkeys to form the identity-difference concept from a minimum number of instances constructed with two stimuli if the appropriate procedure is adopted.

The purpose of the present experiments is (a) to check the possibility for monkeys to form the identity-difference concept from a set of instances constructed with a minimum number of stimuli, and (b) to analyze the effects of some independent variables other than the number of stimuli on establishing relatively strong stimulus control by the identity-difference relation of the stimuli.

EXPERIMENT 1

Malott and Malott (1970) and Malott et al. (1971) trained pigeons to discriminate matching pairs of stimuli from non-matching pairs successively. A circular key was vertically divided into two equal areas, and pecking the key was reinforced with a variable-interval schedule when the colors on both sides matched, but pecking was extinguished when two colors did not match, or vice versa. Only two colors were used for training. After mastery, transfer performances to two new colors were tested in an extinction procedure. Most of their pigeons showed successful transfer. Carter and Werner (1978) criticized these studies in that they might have shown no more than the discrimination between circles (when colors on both sides matched) and two semicircles (when colors did not match), and not the formation of the identity-difference concept. Notwithstanding Carter and Werner's criticism, Malott and co-workers' attempts suggest a possibility that lower animals form the identity-difference concept from a minimum number of stimuli. This possibility was checked by the following experiment in Japanese monkeys, using a free-operant procedure similar to that of Malott and co-workers, with a completely independent presentation of the two stimuli to answer Carter and Werner's criticism.

Method

Subjects

Four Japanese monkeys (Macaca fuscata fuscata) served as subjects. Subject T373 (male, 3 yrs. old) and 0393 (female, 3 yrs. old) had been artificially reared since birth, and had chain-pulling, lever-pressing, and other laboratory experiences. But, they had not experienced any discrimination task which incorporated identity-difference judgment. The other two five-year-old male subjects (T320 and K371) were trained in a higher-order conditional discrimination task consisting of a matching-to-sample and an oddity-from-sample task with red and purple in the previous study (Fujita, Note 3). However, these two subjects showed no transfer to new colors in that study. Furthermore, they have not been trained to match colors other than red and purple, which were used in this experiment as baseline stimuli. Body weights of the four subjects were maintained at approximately 95 % of their free-feeding weights.

Call for Figure 1.

Apparatus

The experimental chamber (70 cm X 70 cm X 70 cm) was located in a dark room. White noise was used to mask external sounds. A houselight was at the top of one wall of the chamber and a feeder tray was at the bottom of the wall. The experimental panel (Figure 1) was attached to the wall. Five transparent acrylic keys (35 mm wide and 50 mm high) were arranged horizontally in the center of the panel, each key separated 55 mm, center to center. A barrier, which projected 20 mm inside, was 10 mm below these keys. Three

levers (35 mm wide and 17 mm long) were attached 20 mm below the barrier. Keys were respectively labeled key 1, key 2, key 3, key 4, and key 5, from left to right, and each lever was similarly labeled lever 1, lever 2, and lever 3. In-line projectors (I. E. E.) installed behind these five keys could present seven colors as stimuli (red, purple, blue, bluegreen, yellowgreen, yellow, and white) and one figure (white dot). Each lever could be illuminated independently by a 24-V tungsten lamp through a slit just above the lever. Either raisins or soybeans were used as reinforcers according to each subject's taste. A universal feeder (D. S. I.) served the reinforcer into the feeder tray. A 24-V tungsten lamp illuminated the tray. Two kinds of buzzer (the reinforcement-buzzer and the timeout-buzzer) were outside the chamber. A minicomputer (DEC PDP-8/f) controlled the equipment. Data were recorded by the minicomputer and a cumulative recorder (Ralph Gerbrands). Subjects' performances were monitored by a TV camera.

In this experiment, two keys (key 4 and key 5) were used as discriminanda, and one lever (lever 3) was used for responding.

Procedure

Baseline training. After shaping responses to lever 3, two sessions were conducted with a variable-interval (VI) 1-sec schedule for the lever-pressing responses. The baseline discrimination training was begun on the next day.

Each trial started with the presentation of two stimuli, red or purple on keys 4 and 5. Responses to lever 3 were

reinforced according to a VI schedule when the two colors were identical (positive trials: red-red and purple-purple), but responses were extinguished when the colors were different (negative trials: red-purple and purple-red). In the initial two sessions, the VI value was 5 sec, and positive trials ended with a reinforcement. In the third session and thereafter, the reinforcement schedule was VI 20-sec, and positive trials ended with a reinforcement or a lapse of 20 sec whichever came earlier. In either condition, negative trials continued for 20 sec. A reinforcement-buzzer sound of 1 sec and 2-sec illumination of the feeder tray accompanied the reinforcement. A response to the lever during the intertrial interval period reset the timer. Intertrial intervals of 3 sec followed the trial. A session consisted of 60 reinforcements.

The accuracy of performance was calculated with the following formula: $\frac{Rp}{Rp + Rn} \times 100$, where Rp was the rate of responding in the positive trials and Rn was the rate of responding in the negative trials. The training continued until the accuracy scores exceeded 90 in two successive sessions. As the rate of responding in negative trials for three monkeys (all but T373) did not decrease sufficiently, negative trials were changed to last until subjects paused for 20 sec in the appropriate session. In this quasi-DRO (differential-reinforcement-of-other-behavior) condition, Rn was calculated as the rate of responding during the initial 20 sec of each negative trial.

Transfer test. After reaching criterion, the quasi-DRO contingency in the negative trials was removed. The mean

duration of the VI was gradually lengthened to 60 sec, and the limit of the number of reinforcements per session was decreased to 30. The transfer test was conducted after the same criterion was satisfied.

The test session consisted of 96 trials, half of which were the baseline trials and the other half were the test trials. In the test trials, only two new colors (blue and bluegreen for T373 and K371, and yellow and yellowgreen for 0393 and T320) appeared. These trials were randomly presented, except that the initial four trials of the session were the baseline trials. All responses were extinguished after two reinforcements in the initial four baseline trials. Each trial lasted 20 sec.

One monkey (K371) received an additional transfer test. After three recovery sessions, he was trained with three colors (adding blue to red and purple) under a VI 60-sec schedule. After reaching the criterion described above, his transfer performances to yellow and yellowgreen were tested. This test session consisted of 108 trials. The initial 12 trials were the baseline trials. Test trials in which only two new colors were presented and baseline trials randomly appeared with the same frequency in the remaining 96 trials. After three reinforcements in the initial 12 baseline trials, all responses were extinguished. The length of each trial was 20 sec.

Results

The four monkeys acquired the baseline discrimination in

varying number of sessions: T373: 7; O393: 13; K371: 15 and T320: 37 (criterion sessions excluded).

Call for Figure 2.

Figure 2 shows the results of the first transfer test for all monkeys. The vertical axis is the rate of responding per minute for each configuration of stimuli. Each stimulus configuration is shown on the horizontal axis. White bars designate the absolute rate of responding in positive trials, while black bars designate negative trials. Accuracy scores of baseline trials and test trials are shown in each graph.

The baseline performances were not impaired under the extinction condition. One subject (K371) showed a very low rate of responding for all configurations of test stimuli, but the other three monkeys responded with higher rates on both of the two positive test trials compared with each of the negative test trials. The accuracy scores for test trials were nearly 70, which indicated that the rate of responding under positive stimuli was about two times as high as that under negative stimuli.

As indicated in the "Procedure" section, K371 was trained with three colors including blue in addition to red and purple after this test session. In the first session of the three-color training, the accuracy score for five configurations including a new color (i.e., blue-blue, blue-red, red-blue, blue-purple, and purple-blue) was as high as 77.2. The mean accuracy score of all configurations exceeded 90 in the third session. But, as the rate of

responding was not sufficiently low in two types of negative trials (blue-purple and purple-blue), training was continued with the quasi-DRO contingency introduced in negative trials. The second transfer test was carried out after 13 training sessions.

Call for Figure 3.

The results of this second test of K371 are shown in Figure 3. The baseline performance was perfect. In contrast with the first transfer test, the rates of responding were considerably higher in both types of positive test trials than in either type of negative test trials.

Discussion

As seen in Figure 2, three of the four monkeys showed successful transfer to new colors after two-color training. A confusing phenomenon was that the rates of responding differed in two kinds of positive test trials. The difference, however, seems to reflect the stimulus control by the absolute value of each test stimulus itself. For example, subject 0393 responded more frequently under yellow stimulus than under yellowgreen stimulus. It is predictable from this tendency that her rates of responding should be highest for yellow-yellow configuration, intermediate for yellow-yellowgreen and yellowgreen-yellow, and lowest for yellowgreen-yellowgreen. But the prediction is clearly inconsistent with the actual result. She showed higher

rates of responding in both of the two positive test trials than in the two negative test trials. This was also the case for other two monkeys, T373 and K371. This means that the stimulus control by identity-difference was strong enough to surpass the stimulus control by the absolute values of the test stimuli.

The amount of transfer shown by these three monkeys was not great, but it should be considered that the differential reinforcement of transfer responses was completely excluded, and thus there was no opportunity for learning to occur. The differential reinforcement employed in test sessions has a very critical effect in favoring transfer. A good example is the very high accuracy shown by K371 in his first three-color training session. Subject K371 showed no transfer to blue in his first test session (Figure 2), yet his accuracy score on trials including blue was as high as 77.2 once trained. Thus, one must be cautious in concluding the existence of transfer when the differential reinforcement maintained in the test sessions. Conversely, when even a small amount of transfer is found when no differential reinforcement was used to test transfer, such a finding should be considered significant, for there is nothing to favor transfer. Accordingly, the present results strongly suggest that some Japanese monkeys are able to form the identity-difference concept from a minimum number of stimuli which generalizes, at least, in regard to color.

However, two colors were not a sufficient condition for all monkeys. K371 showed no transfer in his first transfer test. But clear transfer was obtained in his second

transfer test after training with three colors. Thus, three colors seem to be sufficient for Japanese monkeys to form the identity-difference concept, at least with the above procedure.

Fujita (Note 2, 3) demonstrated that two-color matching-to-sample behaviors of Japanese monkeys were only weakly controlled by the identity-difference relation between stimuli. The stimulus control was so weak that it could not be detected until transfer tests were conducted with two stimuli for which successive and simultaneous discriminations between the stimuli had been priorily established. In this experiment, transfer occurred in three of the four monkeys to the stimuli for which no such discrimination training was given, despite the fact that the same color stimuli used in the preceding experiments were adopted as the training stimuli and the test stimuli. This strongly suggests that some differences in the experimental variables of the present procedure and of the standard matching-to-sample procedure are critical in establishing a relatively strong stimulus control by the general relation of stimuli. This problem was investigated in the following experiments.

EXPERIMENT 2

Some previous transfer studies with pigeons, other than those of Malott and co-workers can be regarded as showing relatively strong stimulus control by identity-difference. The first was Honig's study (1965), in which a pair of hue was projected on two keys. Responses to one key were reinforced with a VI schedule when the two hues had a small difference in wavelength, and responses to another key were reinforced when the two hues had a large difference. Several hues were used for training, and transfer to many new combinations of stimuli including several new hues was tested in an extinction procedure. The proportion of responses to each of the two keys elegantly showed stimulus control along the identity-difference dimension in hue.

The second relevant study was Urcuioli and Nevin (1975), who devised a modified three-key matching-to-sample procedure. They separated the presentation of two comparison stimuli. Pecking the comparison stimulus was immediately reinforced if it matched the sample, but subjects had to refrain from pecking for a while if the non-matching comparison stimulus appeared on one side-key until the matching comparison stimulus on the other side-key substituted for the non-matching stimulus. A peck to this matching key was also reinforced. After mastery of this three-hue training, pigeons were trained with two added novel hues. In these new trials, latencies for pecking were shorter for matching stimuli than for non-matching stimuli. Thus the transfer to new hues was suggested. Urcuioli

(1977) obtained similar results with contingencies of reinforcement reversed.

The third example is Zentall and Hogan's study (1978). They inserted "negative instance" trials among standard matching-to-sample (or oddity-from-sample) trials with two shape stimuli. In the "negative instance" trials, both of the two comparison stimuli did not match the sample for matching birds, and both matched the sample for oddity birds. Subjects were trained to pause until the end of the trial in the "negative instance" trials. The transfer training was conducted for two colors with the task shifted (i.e. from matching to oddity, or vice versa), or non-shifted (i.e. from matching to matching, or oddity to oddity). The non-shifted birds showed more transfer to the new problem than the shifted birds.

One common aspect in the above procedures (and in the procedure adopted in Experiment 1, also), which should be pointed out here, is establishing two different responses independently to positive stimuli and negative stimuli. Assuming that these studies correctly demonstrated concept formation, this factor common to all the studies cited should have an important effect in establishing relatively strong stimulus control by identity-difference. If this factor is critical, a Yes/No procedure for matching and non-matching stimuli ought to establish strong relational control. Three colors, which Experiment 1 suggested as the sufficient condition for concept formation by the four monkeys, were used for training.

Method

Subjects

Two male Japanese monkeys, T271 (7 yrs. old) and M532 (6 yrs. old) served as subjects. Both subjects had been trained with three colors on a simultaneous discrimination of a pair of matching stimuli and a pair of non-matching stimuli similar to Robinson's procedure (1955), just before this experiment. Body weights of the subjects were maintained at approximately 95 % of their free-feeding weights.

Apparatus

The apparatus was the same as in Experiment 1. In this experiment, three keys (key 3, key 4, and key 5) and two levers (lever 2 and lever 3) were used. The three colors used in the animals' previous training were chosen as the baseline stimuli.

Procedure

Baseline training. After shaping the necessary response sequence, the discrimination training started. A white dot (10 mm in diameter) was presented on key 3 at the start of a trial. After three responses to the key (self-start responses), key 4 and key 5 were simultaneously lighted as red, purple or blue. When the two colors matched ("same" trials: red-red, purple-purple, and blue-blue), pressing lever 3 just under these two keys ("Yes" response) was a correct response, and pressing lever 2 ("No" response) was an incorrect response. Conversely, when the two colors did not

match ("different" trials: red-purple, purple-red, red-blue, blue-red, purple-blue, and blue-purple), a "No" response was correct and a "Yes" response was incorrect. The "same" trials and the "different" trials were randomly presented with the same frequency. Correct responses were reinforced by a soybean or a raisin accompanied by 1-sec reinforcement-buzzer sound and 2-sec illumination of the feeder tray. Incorrect responses were followed by a 5-sec timeout accompanied by a timeout-buzzer sound of 1 sec. The houselight was turned off during the timeout periods. Intertrial intervals of .5 sec followed the reinforcement cycles and the timeout periods. Any response during the intertrial intervals and timeout periods reset the timer.

Second-order variable-ratio (VR) schedules were introduced as the training proceeded. A reinforcement was made after several correct responses. Correct responses which did not satisfy the VR were followed by a short reinforcement-buzzer sound of .5 sec. Incorrect responses did not affect the VR counter. Each session was ended with 80 reinforcements. Training was continued with a non-correction procedure except that a correction procedure was utilized in order to remove the subjects' position preferences for a few sessions. Both subjects were trained to reach a criterion by which the percent of correct responses in any entire session exceeded 90 for two successive sessions.

Transfer test. After reaching the criterion, both subjects were overtrained by the following procedure. As T271 reached the criterion with the VR 1 schedule (the same

as the continuous-reinforcement schedule), the VR value was gradually increased to 4. M532 met the criterion with the VR 4 schedule, and the value was increased to 6. Then, "non-effective" trials were introduced. In the non-effective trials, no differential reinforcement was made regardless of the subject's Yes/No responses. An intertrial interval immediately followed the response. The responses in the non-effective trials had nothing to do with the VR counter. The number of the non-effective trials was gradually increased, and the VR value was accordingly lowered to keep the rate of reinforcement unchanged. Finally, half of the trials were non-effective, and the VR value was two for T271 and three for M532. The following tests were conducted after the above criterion was satisfied, and, in addition, the percent of correct responses for each configuration of stimuli averaged more than 80 for the two sessions.

A test session consisted of 1/2 baseline trials, 1/4 non-effective baseline trials, and 1/4 non-effective test trials. Three kinds of "same" test trials and six kinds of "different" test trials were constructed from three new colors -- bluegreen, yellowgreen, and yellow -- as was done for the three baseline colors. The "same" test trials and the "different" test trials appeared randomly with the same frequency. Tests were conducted for three sessions with the limit of 80 reinforcements per session.

Call for Figure 4.

Results

The baseline training was completed in seven sessions by T271, and in 18 sessions by M532 (with criterion sessions excluded). The number of sessions for overtraining before testing was 16 for T271 and 19 for M532. The results of the transfer tests are shown in Figure 4. The vertical axis designates the percent of correct responses, while the horizontal axis designates each test session. Open symbols are the baseline trials and filled symbols are the test trials in which only new stimuli appeared. Both subjects showed accurate performances for baseline trials throughout the test period. But their accuracy percents for transfer were very low compared with those obtained in Experiment 1.

Discussion

Both subjects showed very little transfer, although the results in Experiment 1 suggested that three colors were sufficient to establish a strong relational control. The results did not support the hypothesis that the establishment of two different responses was important. The apparently inconsistent findings of Urcuioli (1977), Urcuioli and Nevin (1975), and Zentall and Hogan (1978) seem to have been greatly affected by the maintained differential reinforcement adopted by these workers.

The critical effect of this factor to favor transfer was well demonstrated in Experiment 1. Rapid learning should generally occur in test sessions. We must not overestimate

apparently positive transfer obtained with differential reinforcement. Such a procedure should be called "transfer training", not "transfer test". The need for such caution is supported not only by the present experiment, but by the results obtained by Cohen (1969), who used an adjustable comparison procedure which seems to guarantee two independent responses to matching and non-matching stimuli. With a two-key situation, she trained pigeons to peck the comparison key repeatedly until it matched the sample, and to peck the sample key once the two colors matched. She reported that whenever a new sample stimulus appeared, the pigeons performed as if it were one of the old stimuli, and no transfer was observed.

Accordingly, although the findings obtained in Urcuioli (1977), Urcuioli and Nevin (1975), and Zentall and Hogan (1978) may not be completely discounted, the amount of transfer obtained should be considered to have been greatly corrected. Any work which intends to demonstrate transfer must at least exclude all possibilities of learning during testing which favor transfer. Otherwise, the obtained results purporting to show transfer cannot be positively supported as such, nor can they be denied completely.

The results of Experiment 2 can be reasonably interpreted to mean that the establishment of two different responses to matching and non-matching stimuli is not critical, although it may have some effect, to produce a strong stimulus control by identity-difference. If this factor were critical, transfer should have occurred without differential reinforcement.

EXPERIMENT 3

Experiment 2 clarified that the establishment of two independent responses was not critical. Another factor common to the studies discussed above which showed transfer free from the defects of the differential reinforcement -- that is, Malott and Malott (1970), Malott et al. (1971), Honig (1965), and Experiment 1 of the present study -- is, of course, the adoption of VI schedules within trials. The following experiment examined the effect of this factor on the formation of the identity-difference concept by comparing the amount of transfer between a standard matching-to-sample procedure and a modified procedure adopting a within-trial VI schedule.

Method

Subjects

Three artificially reared three-year-old Japanese monkeys, T441 (male), T442 (female), and T446 (male) served as the subjects. All subjects had experiences with chain-pulling, simple lever-pressing, and so on. But they had not experienced any discrimination task which incorporated identity-difference judgment. Body weights of the subjects were kept at approximately 95 % level of their free-feeding weights.

Apparatus

The apparatus was the same as in Experiment 1. In this

experiment, only lever 1 and keys 2, 3, 4 were used.

Procedure

Baseline matching-to-sample (MTS) training. After shaping the necessary response chain, the baseline training started. Each trial began with lighting lever 1. Three responses to the lever (self-start responses) turned off the lever-light, and produced a sample stimulus on key 3. After five responses to the sample (observing responses), two comparison stimuli appeared on both sides (key 2 and key 4) while the sample remained. One matched the sample, and the other did not. A response to the matching comparison stimulus was a correct response, and a response to the non-matching comparison stimulus was an incorrect response. This is a typical simultaneous matching-to-sample procedure. With the same procedure as in Experiment 2, correct responses were reinforced and incorrect responses were followed by a 5-sec timeout. Intertrial intervals were .5 sec in duration. Second-order VR schedules were also appropriately introduced. All possible configurations of three colors (red, purple, and blue as in Experiment 2) were used for this baseline training. Each session consisted of 80 reinforcements. A correction procedure was utilized for a few sessions in order to remove the subjects' position preferences. This continued until the percent of correct responses exceeded 90 for two successive sessions.

MTS transfer test 1. After reaching the criterion, all the subjects were overtrained with the following procedure. The value of the VR was gradually equalized to four for all

subjects. Then, non-effective trials were introduced and gradually increased in number to occupy a half of the trials, and, at the same time, VR value was lowered to two. The following tests were carried out after the same criterion adopted for conducting transfer tests in Experiment 2 was satisfied. Each test session consisted of 1/2 baseline trials, 1/4 non-effective baseline trials, and 1/4 non-effective test trials in which all possible combinations of three new colors (bluegreen, yellowgreen, and yellow) were presented. The VR value was kept to two. Tests were conducted for three sessions with the limit of 80 reinforcements per session.

Baseline training of a free-operant matching-to-sample (FMTS). After the above tests were finished, one baseline MTS session was conducted with a continuous-reinforcement (CRF) schedule. In the next session, the intertrial interval was lengthened to 5 sec, and both the self-start responses and observing responses to the sample were decreased to two. Free-operant matching-to-sample training began on the next session.

A FMTS trial proceeded in the same way as in the preceding MTS trials. The main difference was that responses to the matching comparison stimulus (correct responses) were intermittently reinforced with VI schedules, and that responses to the non-matching comparison stimulus (incorrect responses) were extinguished (not followed by a timeout). Thus, the reinforcement schedule employed here for FMTS procedure can be described as: mult(conc VI EXT)$_n$ -- a multiple schedule of concurrent schedules of

variable-interval and extinction. Whenever an incorrect response occurred, reinforcement of a correct response was delayed for a predetermined duration (error-delay).

Slightly different procedures were employed for the three subjects. For T441, the VI value was gradually increased from 1 sec to 60 sec, and the error-delay duration was also gradually lengthened from 0 sec to 5 sec. By this stage, each trial ended with a reinforcement. Next, the time-limit of each trial was set up. Each trial ended with a reinforcement or the time-limit whichever came earlier. The time-limit was gradually shortened from 60 sec to 20 sec. Thus, the last condition was: VI 60-sec with the time-limit of 20 sec and error-delay of 5 sec.

For the other two monkeys (T442 and T446), the VI time was first lengthened from 1 sec to 15 sec. The time-limit of each trial was set up at this stage. Then, the VI value was further increased gradually to 60 sec. The duration of the error-delay was also gradually lengthened to 20 sec for these two subjects. Thus, the last condition for these two subjects differed from that of T441 in the duration of the error-delay. In both cases, a session continued until 80 reinforcements were made for shorter VI times (no longer than 30 sec), and 40 reinforcements for longer VI times (45 sec and 60 sec). The time of the VI was not lengthened until consistent responding was obtained in each of the VI values. The training continued until the percent of correct responses to total responses exceeded 90 for two successive sessions, and, in addition, that the average for the two criterion sessions was higher than 80 for each configuration of

stimuli.

FMTS transfer test. After reaching the criterion, test trials were substituted for a quarter of the trials. As in the MTS transfer test 1, all possible configurations of test stimuli (bluegreen, yellowgreen, and yellow) were randomly presented. All responses, correct or incorrect, were simply extinguished in the test trials. Each test trial lasted for 20 sec. On baseline trials which comprised three quarters of all the trials, correct responses were reinforced with a VI 45-sec schedule. Other experimental variables were the same as in the preceding baseline session. Tests were conducted for three sessions with the limit of 40 reinforcements or 2 hr whichever came earlier.

Recovery MTS training. After three sessions of the FMTS transfer test, all subjects received baseline MTS training again with a CRF schedule. The requirements of the self-start responses and the observing responses were unchanged (i.e., two). Intertrial intervals were shortened to .5 sec again. The second-order VR schedule and the non-effective trials were introduced as in the initial baseline MTS training. Lastly, half of the trials were non-effective, and VR was two.

MTS transfer test 2. After the criterion adopted for the MTS transfer test 1 was satisfied, the transfer test was again carried out as in test 1.

Results

The baseline MTS performance was acquired in 28 sessions

by T441, 31 sessions by T442, and in 8 sessions by T446 (with criterion sessions excluded). The VR value when the subjects reached the criterion was 2, 4, and 1, respectively. The number of overtraining sessions before the MTS transfer test 1 was 16 for T441, 13 for T442, and 28 for T446. The number of sessions spent to train the subjects to reach the FMTS criterion was 20 for T441, 29 for T442, and 29 for T446. All subjects performed fairly well in their recovery MTS session after FMTS transfer test. The alteration in the duration of intertrial intervals and in the number of the self-start and the observing responses had no effect on the accuracy of the subject's performance.

Call for Figure 5.

The results of the three tests are shown in Figure 5. The vertical axis designates the percent of correct responses, and the horizontal axis designates each session. Open symbols are the baseline trials, and filled symbols are the test trials.

All subjects showed good baseline performances (open symbols) throughout the test periods. During the sessions of the MTS transfer test 1 (the left panel), accuracy percents of the test trials (filled symbols) were no more than 60 except that T441 showed a somewhat successful performance in his first session. However, all three subjects showed higher accuracy percents in the test trials in the first session of the FMTS transfer test (the center panel, filled symbols). T446 showed an even better

performance in the second session. Transfer performances of the other two monkeys deteriorated to a very poor level in the second and the third sessions. The deterioration was caused by the extremely low rates of responding in test trials. The highly successful transfer performance shown by T446 also disappeared in the third session, although he responded with a relatively high rate.

The results of the MTS transfer test 2 (the right panel) were not consistent among subjects. Two monkeys performed very well in the test trials for two sessions. But their performances gradually deteriorated as sessions were repeated. On the other hand, T442 performed very poorly in test trials throughout the test periods.

The averaged accuracy percent for the three subjects in the test trials of the first session of the FMTS transfer test significantly increased from that of each session of the MTS transfer test 1. (t = 3.48, 4.79, 6.64, respectively. df = 2. All of them were statistically significant at the .05 level.)

Discussion

The result that only a small amount of transfer was observed in the MTS transfer test 1 was consistent with other studies with monkeys dealing with transfer of matching-to-sample performances with a small number of stimuli (Fujita, Note 2, 3; Kojima, 1979; Mello, 1971). No clear transfer was demonstrated in these studies. Only Jackson and Pegram (1970) reported the "perfect" transfer of

three-color simultaneous matching-to-sample performances by rhesus monkeys to a fourth color. Their report was quite conspicuous in the literature. It is possible that their data were favored to show transfer by the monkeys' history of delayed matching, by the small number of test stimuli (only one color), and by maintaining differential reinforcement. Thus a replication of their experiment is necessary.

In the FMTS transfer test, all three subjects showed better transfer performances than in the MTS transfer test 1. Although T441 showed only a small gain, the other two monkeys showed a great increase in accuracy percents. T446, especially, performed with accuracy as high as 80 % correct in his second session of the FMTS test. The deteriorated performances of all subjects in later sessions of the FMTS transfer test were the consequence of repeated presentation of stimuli in which responses were never reinforced. Thus, the deterioration is neither surprising nor important. What is important is the significant increase in the subjects' accuracy percents for transfer in the first session of the FMTS transfer test compared with those in each of the three sessions of the MTS transfer test 1. The increase in the accuracy percents seems to reflect the effect of the use of the within-trial VI schedule.

It is possible that overtraining of matching behavior itself might be effective in increasing accuracy percents for transfer. Unfortunately, the present experiment cannot answer this question. However, successful transfer was demonstrated not only in this experiment but in all previous experiments which employed within-trial VI schedules

including Experiment 1. Furthermore, after mastery of the baseline MTS task, all subjects received a relatively good amount of overtraining before the MTS transfer test 1 was conducted. Thus, the effect of the overtraining itself seems to have been small. The within-trial VI schedule seems to have played a major role to improve transfer accuracy.

There are two possibilities for the effect of this within-trial intermittent-reinforcement procedure to improve transfer accuracy. One is that the procedure actually strengthens the stimulus control by identity-difference, and the other is that the procedure simply provides a sensitive measure. But, choice between the two possibilities is clear. The high accuracy percents for transfer shown by two subjects during the MTS transfer test 2 support the former possibility. If the procedure merely provided a sensitive measure, the amount of transfer in this second test could not have increased in comparison with those in the MTS transfer test 1. The poor transfer performances shown by T442 raises questions about this possibility. However, a glance at Figure 5 reveals that repeated presentation of the same stimuli without reinforcement decreases the accuracy percents on trials presenting those stimuli. It is predictable that the other two monkeys' transfer performances would decrease to a chance level with repeated tests. Subject T442 may have been very sensitive to the repeated presentation of stimuli without reinforcement. Thus, one may conclude that the use of a within-trial intermittent-reinforcement procedure has the effect of strengthening stimulus control by

identity-difference.

GENERAL DISCUSSION

The ability for abstraction of Japanese monkeys was investigated in Experiment 1 by analyzing an apparently conceptual behavior established with a small number of stimuli. Nissen, Blum, and Blum (1948) might be regarded as having shown positive evidence that chimpanzees formed the concept from a minimum number of stimuli, using a two-object matching-to-sample procedure. Unfortunately, they not only maintained differential reinforcement of the apes' transfer responses but also a correction of incorrect responses. Further, they did not show early transfer performances. Thus, the work cannot be considered to have clearly demonstrated transfer. Within the author's knowledge, no clear evidence has been reported either in monkeys or in apes that these animals can form the identity-difference concept from a minimum number of stimuli. However, Experiment 1 demonstrated that some Japanese monkeys are able to form the identity-difference concept from a minimum number of stimuli which generalizes at least within colors, and thus, made it clear that they possess a rather good ability for abstraction. The procedure employed in this experiment made it possible to reveal this good ability.

Furthermore, Experiments 2 and 3 suggested that the main factor which increased the abstractness of the behavior was an intermittent-reinforcement schedule adopted within trials. The effect of this factor seems to be greater than it appears. For example, pigeons, which were unable to form the identity-difference concept in standard

matching-to-sample procedures with numerous stimuli (Holmes, 1979; Carter & Taten, Note 1), were able to do so with a minimum number of stimuli when a within-trial VI schedule was used (Malott & Malott, 1970; Malott et al., 1971). Carter and Werner (1978) criticized the Malott research by pointing out the possibility that the pigeons' behavior was based on a discrimination between circles and two semicircles. The circle-semicircle problem may be considered a minor problem, however, as Honig (1965) demonstrated successful transfer with a within-trial VI schedule. It might be possible to demonstrate the formation of the identity-difference concept in many other phyletically lower animals by using within-trial VI schedules.

The present experiments produced a very interesting fact: using a color matching procedure, an intermittent-reinforcement schedule employed within trials has the effect of strengthening stimulus control by the general relation between stimuli. This raises two questions: first, how general is this finding? Does a VI schedule generally strengthen stimulus control by the general relation among many kinds of stimuli? If so, this procedure can be applied to many other relational concepts such as larger-than, longer-than, more-numerous-than, and so on. It may be possible to demonstrate the formation of many abstract relational concepts in nonhuman animals. The generality of this finding should be studied further.

The second question is more important: which aspect of a VI schedule is critical for establishing strong relational control? One possibility is that a simple decrease in the

rate of reinforcement might be important for such strong relational control. In Experiment 3, in fact, the rates of reinforcement per minute in the FMTS sessions with a VI 60-sec schedule were between .5 and .7, which were considerably lower than those in the MTS sessions with a second-order VR 4 schedule (between 3.0 and 3.5). However, a contradictory finding was reported by Ferster (1960). He demonstrated that pigeons' matching-to-sample accuracy decreased when their matching behaviors were intermittently reinforced with second-order interval schedules, in contrast with improving effects of fixed-ratio schedules. Thus the effect of a simple decrease in the rate of reinforcement itself to strengthen the relational control seems to be doubtful.

Another hypothesis is possible. At least two training schedules are known to produce flatter generalization gradients after single-stimulus training than VI schedules do. One is the differential-reinforcement-of-low-rates-of-responding (DRL) schedule reported by Hearst, Koresko, and Poppen (1964), and the other is the variable-ratio schedule reported by Thomas and Switalski (1966). Rilling (1977) interpreted these phenomena as the consequence of dual stimulus control: control by previous responses (factor A) and control by external stimuli (factor B). He argued that "when factor A is important, as on DRL and (perhaps) ratio schedules, then factor B is correspondingly less so; hence the flatter gradient." (p. 436). On VI schedules, as the rate of reinforcement is hardly affected by the rates and the patterns of responding, factor A seems to be unimportant.

Therefore the external control is stronger in VI schedules than in DRL or ratio schedules. This advantage of VI schedules found in single-stimulus training ought to work in discrimination situations. In discrimination situations, enhanced external control will make it possible for insalient aspects of stimuli which do not easily control behavior (such as identity-difference) to increase their controlling function as a discriminative stimulus. Thus, it is possible that the potential of VI schedules to enhance external control might be the most critical factor to strengthen the stimulus control by identity-difference.

Unfortunately, no relevant study to examine the appropriateness of this hypothesis has been reported yet. Lydersen, Perkins, and Chairez (1977) is the only study to give some information about this problem. They showed that the increase in the fixed-ratio requirement to comparison stimuli (within trials) lowered the accuracy of pigeons' oddity-from-sample performances. Assuming that the decrease in accuracy reflected weakened stimulus control by identity-difference, this finding could support the above hypothesis, because, as Rilling (1977) suggested, ratio schedules would make the external control weak. But such interpretation should be made with much caution. The decrease in accuracy might be derived from some other factors. Therefore, the work by Lydersen et al. cannot give a clear answer to the question about the appropriateness of this hypothesis.

There are many other aspects which might strengthen the relational control in a VI schedule: for example, a simple

increase in the duration of the stimulus presentation, an increase in the number of responses emitted to the stimulus, unpredictability of reinforcement, and so on. The effects of these aspects have not been investigated yet in the relevant situations to the present study. A more appropriate procedure to study relational concepts in animals can be established if the critical aspect to strengthen stimulus control by the general relation among stimuli is determined. Further investigations are necessary.

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FOOTNOTES

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2. Carter and Werner (1978) implied that these learning-set studies might not suggest the identity-difference concept by pointing out the possibility of learning several stimulus-specific rules based on the color of the objects employed. Schrier and Thompson (1980) argued against the criticism of Carter and Werner by stating that such multiple-rule learning could not account for the monkeys' behavior for several reasons.

FIGURE LEGENDS

Figure 1. Front view of the experimental panel attached to one wall of the experimental chamber. The barrier projected 20 mm inside. Keys were respectively labeled key 1, key 2, key 3, key 4, and key 5, from left to right, and levers were similarly labeled lever 1, lever 2, and lever 3. In-line projectors attached behind these keys could present seven colors and one figure on each key.

Figure 2. The results of the transfer test of Experiment 1 (from red and purple to either of blue and bluegreen or yellow and yellowgreen, each of which is abbreviated as: R, P, B, BG, Y, and YG.). The vertical axis designates the rate of responding per minute for each configuration of stimuli. Note that the gradations differ among subjects. White bars denote positive trials, and black bars denote negative trials. The accuracy scores (see text.) in baseline trials and in test trials are shown above each graph. Three of the four monkeys showed successful transfer to new colors.

Figure 3. The result of the second transfer test for K371, who failed to transfer with two-color training, after training with three colors (red, purple, and blue) in Experiment 1. This time, the subject showed successful transfer to two new colors (yellow and yellowgreen). Other details as in Figure 2.

Figure 4. The results of the transfer test in Experiment 2 (from red, purple, and blue, to bluegreen, yellowgreen, and yellow). The percent of correct responses are shown in the vertical axis. The horizontal axis designates each test session. Open symbols denote baseline trials and filled symbols denote test trials. Both monkeys showed very little transfer.

Figure 5. The results of the three transfer tests in Experiment 3. The percent of correct responses are shown in the vertical axis. The left panel is the transfer test 1 of the matching-to-sample (MTS), the center panel is the transfer test of the free-operant matching-to-sample (FMTS), and the right the transfer test 2 of the matching-to-sample. In the baseline FMTS trials, responses to a matching comparison stimulus were reinforced with a variable-interval schedule. Open symbols designate the baseline trials (red, purple, and blue), and filled symbols designate the test trials (bluegreen, yellowgreen, and yellow). Note that all three subjects showed better transfer performances in the first session of the FMTS than in the transfer test 1 of the MTS.

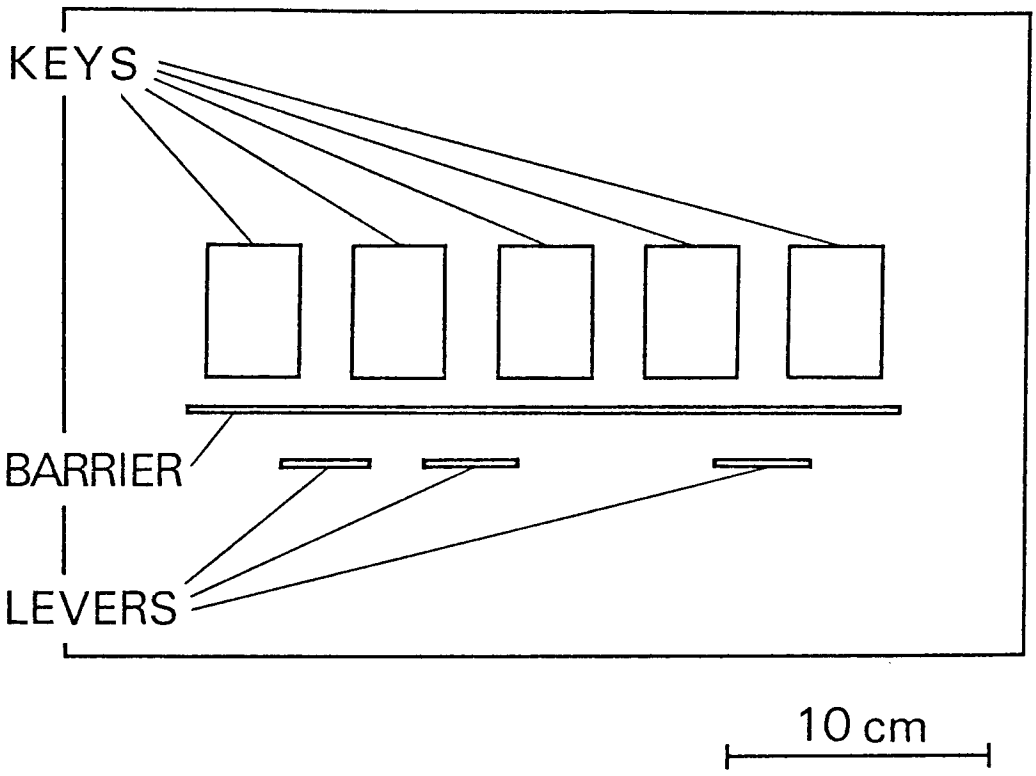
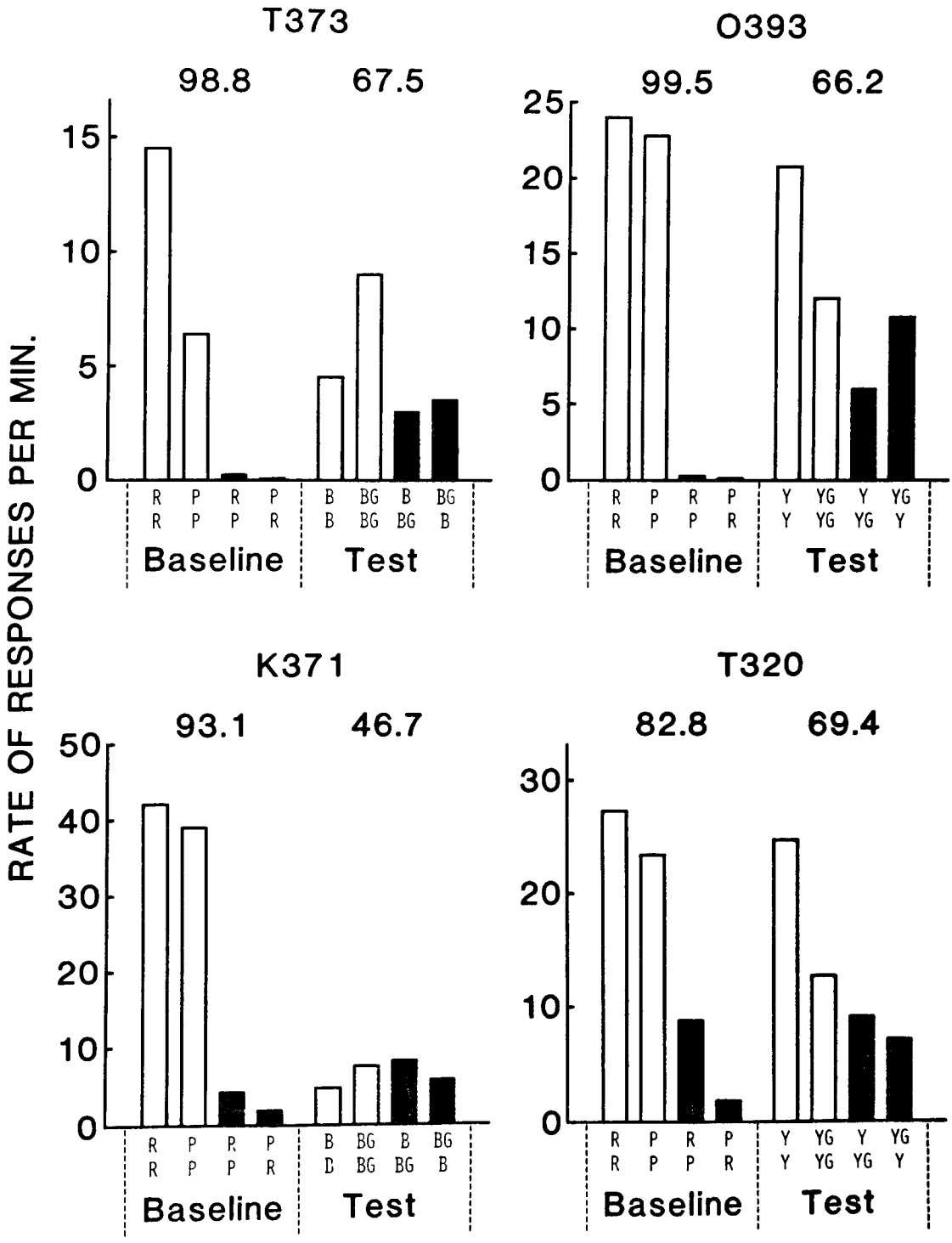


Figure 1.


T373
98.8
67.5
O393
99.5
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K371
93.1
46.7
T320
82.8
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RATE OF RESPONSES PER MIN.
Baseline
Test
R R
P P
R P
P R
B B
BG BG
B BG
BG B
Y Y
YG YG
Y YG
YG Y

Figure 2.

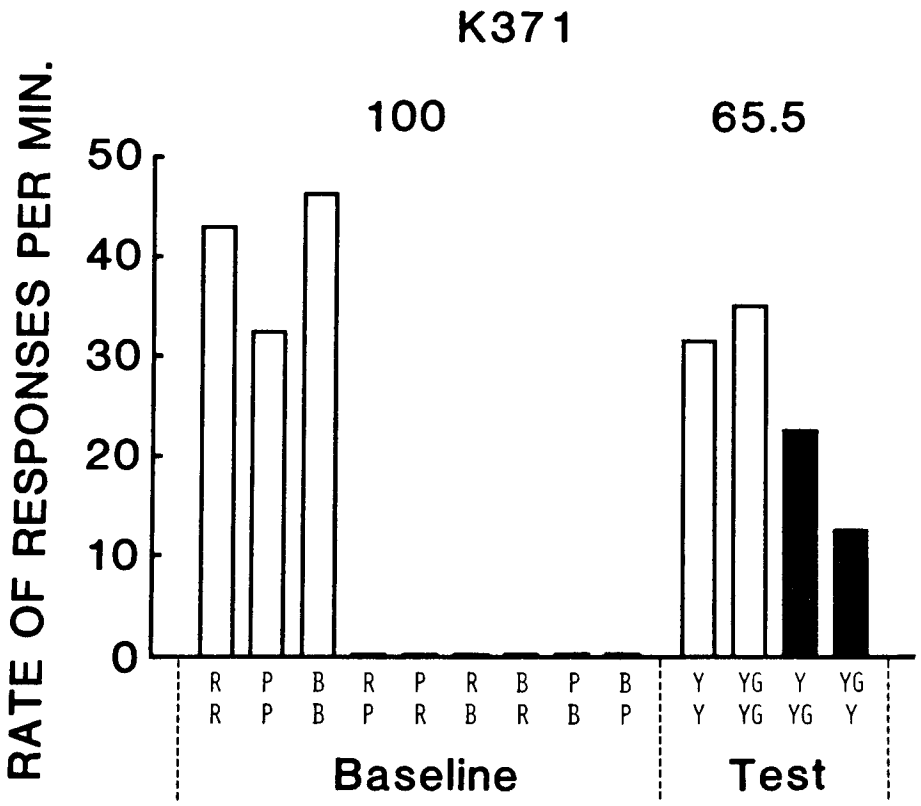
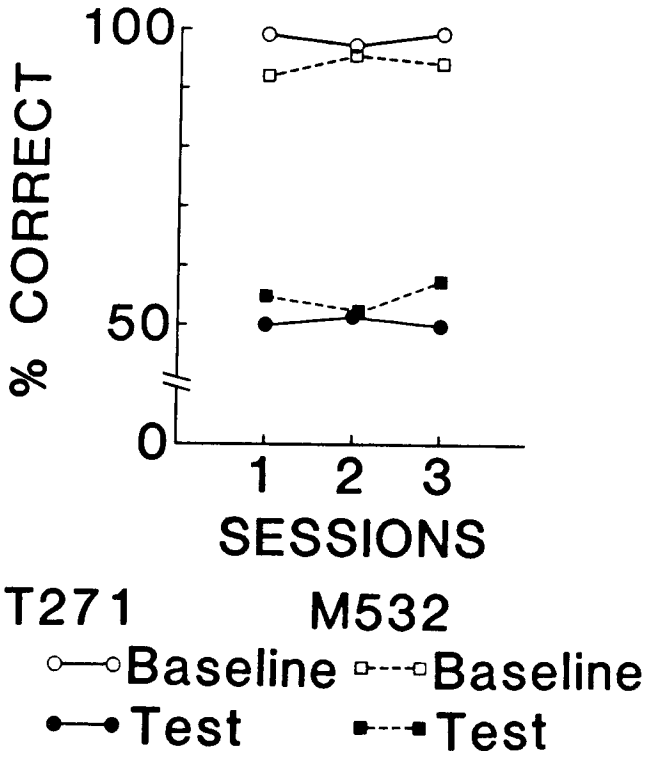

K371
100
65.5
RATE OF RESPONSES PER MIN.
50
40
30
20
10
0
R R
P P
B B
R P
P R
R B
B R
P B
B P
Y Y
YG YG
Y YG
YG Y
Baseline
Test

Figure 3.


100
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1 2 3
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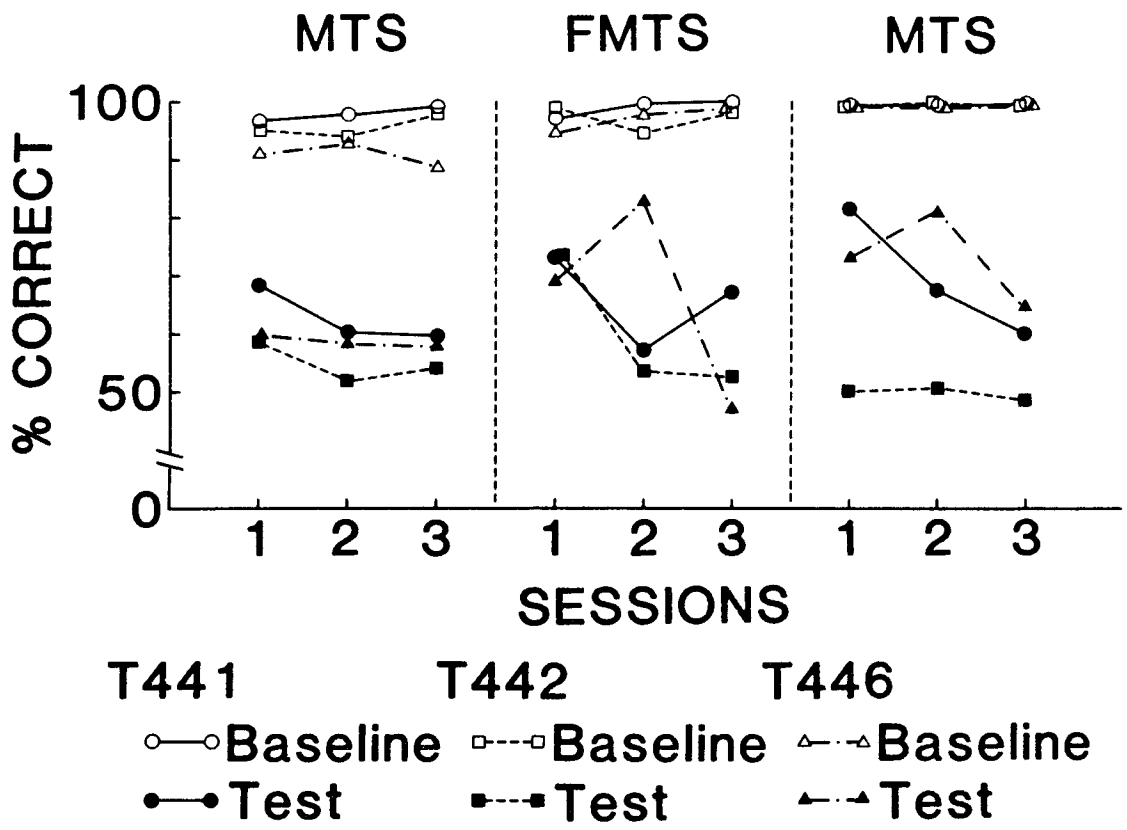
Figure 4.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Baseline
Baseline
Test
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Test

Figure 5.

An analysis of stimulus control in two-color matching-to-sample behaviors of Japanese monkeys (*Macaca fuscata fuscata*).

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Abstract

An analysis of stimulus control in two-color matching-to-sample behaviors of Japanese monkeys (Macaca fuscata fuscata).

Stimulus control in two-color matching-to-sample behaviors of Japanese monkeys was analyzed by examining transfer performances to new colors, using "non-effective" trials in which no differential reinforcement was made regardless of Ss' responding. This procedure also kept the rate of reinforcement in test sessions from decreasing. In experiment 1, no transfer to test stimuli and marked preference for familiar baseline stimuli were observed. In experiment 2, repeated discrimination reversal training was conducted with half of the test stimuli beforehand, in order to familiarize Ss with the stimuli and to establish two basic discriminations included in matching-to-sample, namely, the successive discrimination between samples and the simultaneous discrimination between comparison stimuli. Weak transfer to the priorily trained test stimuli resulted, though the preference could not be sufficiently suppressed. It was concluded that (a) identity between sample and comparison stimuli actually controlled, at least partly. matching-to-sample behaviors of Japanese monkeys, even though only two stimuli were used in the training, and that (b) prior establishment of discriminations included in the task made it possible to detect the relational control.

Key words: monkeys, operant conditioning, key press,

stimulus control, concept formation, stimulus generalization, conditional discrimination, matching-to-sample.

Matching-to-sample is one of the conditional discrimination tasks, which requires subjects to select the "same" comparison stimulus as the sample. The task has been widely used as a standard paradigm to investigate animals' intellectual abilities (Weinstein, 1941 ; 1945), short-term memory (D'Amato, 1973), and other physiological problems (Mello, 1971 ; Mishkin, Prockop, & Rosvold, 1962 ; Glick & Jarvik, 1970).

The fact that some nonhuman animals are able to solve matching-to-sample tasks on the conceptual basis of "sameness" — that is, performances safely transfer to new stimuli — has been demonstrated in apes (Nissen, Blum, & Blum, 1948), monkeys (Mishkin, et al., 1962), and dolphins (Herman & Gordon, 1974). But, as French (1965) pointed out, if a limited number of stimuli are used, some specific aspects of the stimuli other than the physical identity of the sample and comparison stimuli might control animals' responding. Although most of the studies which utilized this task as a paradigm employed only a limited number of stimuli, the basic question of what aspects of the stimuli actually control the subjects' responding should a small number of stimuli be used has not been extensively studied except in pigeons.

Carter & Werner (1978) reviewed the literature on pigeons. According to them, there are three possible explanations for the ways how the subjects solve matching-to-sample tasks. The first is what they call "the configuration model" — subjects learn a set of rules to respond in a special way for each of the configurations of sample and comparison stimuli

(e.g. to respond to the left — or red — for red-red-green configuration). The second is "the multiple-rule model" — subjects learn a set of "if..., then..." rules for each sample stimulus (e.g. if the sample is red, then choose red.). The third is "the single-rule model" — subjects learn only one general rule to choose the same comparison as the sample. In terms of stimulus control, the three cases are labelled here: "configuration control", "specific-relation control", and "general-relation control", respectively. They stressed the following two points with regard to pigeons' performances. First, performances were not affected so long as the samples were the trained stimuli, but severely deteriorated if the samples were new stimuli. Second, no differences were found among the mastering processes for the three similar tasks, (a) matching-to-sample, (b) oddity-from-sample, and (c) symbolic matching, providing the number of "if..., then..." rules to be learned was the same. From these considerations, they concluded that pigeons learned only a set of "if..., then..." rules.

However, Carter & Werner's conclusions might not be appropriate for monkeys. Monkeys' matching performances with a small number of stimuli were analyzed by Jackson & Pegram (1970a,b), Mello (1971), and, recently, by Kojima (1979). Jackson & Pegram (1970a) reported "perfect" intradimensional transfer to the fourth color, but "no" extradimensional transfer to a new form. Their later work (1970b) also failed to demonstrate any extradimensional transfer from color to form. In the experiment of Mello (1971), who conducted transfer tests from form to a variety

of intradimensional, extradimensional, and photographic stimuli, one of the three monkeys showed somewhat successful transfer to all types of stimuli, but the other two monkeys did not. Similarly, in Kojima's (1979) transfer tests from form to form, one of the two monkeys appeared to show very weak transfer, but the other monkey showed no transfer. Thus, previous experimental reports on monkeys' performances did not obtain consistent results, and the basic question asked earlier receives no clear answer.

The purpose of the present experiment was to determine which of the three models of stimulus control is appropriate for correctly performed two-color matching-to-sample behaviors of Japanese monkeys, by analyzing intradimensional transfer performances. Two experiments were conducted. In experiment 1, transfer to new stimuli was examined with conditions that excluded both decrease of the rate of reinforcement and the learning factor resulting from the differential reinforcement in tests. In experiment 2, based on the results of experiment 1, familiarity with the test stimuli and their functions as discriminative stimuli were operated.

Experiment 1

In testing with new stimuli, previous workers (Jackson & Pegram, 1970a,b ; Mello, 1971 ; Kojima, 1979) employed the same dependencies of reinforcement as in baseline sessions. Such procedures raise two problems. One is the possibility of learning during the test sessions, and the other is the response instability resulting from a decrease in the rate of reinforcement. These two problems make results inconsistent and difficult to interpret. To exclude such difficulties, "non-effective trials" can be introduced before tests are conducted. For non-effective trials, no feed back is given to the subjects regardless of their responding. That is, no differential reinforcement is made in non-effective trials. At the same time, a second-order variable-ratio (VR) schedule can be employed. When non-effective trials are inserted among other "effective" trials, the value of the VR is correspondingly lowered so as to keep the rate of reinforcement at almost the same level. Test stimuli are introduced in such non-effective trials. By using this strategy, almost all possibilities of learning in the test trials will be excluded, and, furthermore, it is possible to keep the rate of reinforcement in the test sessions approximately the same as that in the baseline sessions, without regard to the accuracies on test trials, as long as the baseline performances do not deteriorate severely. One purpose of the present experiment is to examine the stimulus control in two-color matching-to-sample behaviors of Japanese monkeys using such non-effective trial procedures.

Another purpose is, though a minor one, to examine whether there are any transformations of stimulus control during acquisition processes. In simple discrimination, Nevin (1973) suggested a generalization gradient transforms with the duration of the training period. Similar phenomena might be observed for complex discriminations such as matching-to-sample. For example, the general-relation control might temporarily strengthen at some stages of acquisition. In order to check such a possibility, a set of test stimuli may be presented during the acquisition processes in the form of non-effective trials. (Another set of stimuli are used for transfer tests.)

Method

Subjects. The subjects were two five-year-old male Japanese monkeys (Macaca fuscata fuscata), T320 & K371. Both subjects had experience with a symbolic matching task, but had no experience with matching-to-sample tasks. Body weights of the subjects remained at 90-95 % of their free-feeding weights throughout the experiment.

Apparatus. The experimental chamber (70 cm X 70 cm X 70 cm) was located in a dark room filled with masking white noise. The experimental panel was attached to one side-wall of the chamber. At the top of the panel was a small translucent window (20 mm X 70 mm), which was illuminated by a 24 V tungsten lamp, used as a room light. Three transparent acrylized keys (50 mm X 35 mm) were installed in the middle of the panel, each key separated by 60 mm, center to center. Another small key (25 mm X 35 mm), placed 85 mm

above the top of the center key, was used as a self-start key. I.E.E. in-line projectors were attached behind these keys. A feeder tray was below these operanda. A 24 V tungsten lamp illuminated the tray. Soybeans were used as reinforcers, which were presented in the tray, by a pellet dispenser. A minicomputer (DEC PDP8/F) controlled the equipment. Data were collected by the minicomputer and a cumulative recorder (Ralph Gerbrands). Subjects' performances were monitored with a TV camera.

Procedure. Preliminary training : After responses to a white-lighted key were stabilized, the sequence of responses appropriate to matching-to-sample training was introduced. Initially, the self-start key was white illuminated. Three responses to the key (fixed-ratio 3 : FR3) turned the center key (sample key) lighted white. Ten responses to the center key (FR10) turned off the center stimulus, and white light appeared on either of the two side keys (comparison keys). A response to the lighted side key turned off all the stimuli on the keys, and the response was reinforced by a soybean, accompanied by 1 s horohoro-buzzer sound and 2 s illumination of the feeder tray. A response to the unlit side key was followed by another buzzer sound of 1 s and 5 s time-out. The room light was turned off during time-out periods. Intertrial intervals of 0.5 s followed the reinforcement cycles or the time-out periods. Any response to the keys during an intertrial interval or time-out reset the clock.

After the subjects showed consistent performances, 24 non-effective trials were randomly inserted in every 100 trials. On non-effective trials, the subjects were required

to respond in exactly the same manner as in the other "effective" trials, but no feed-back was given regardless of their responding. That is, intertrial intervals immediately followed a side key response. Three sessions were given with a limit of 80 reinforcements per session. The baseline 0-delay matching-to-sample training was begun on the next day.

Baseline training with test 1 : In baseline training, the temporal sequence of events was exactly the same as that of the preliminary training, but four color stimuli, instead white lighting, were presented on the sample and comparison keys, and a response to the comparison key which had a color matching the sample key was a "correct" response. Among the four color stimuli, red and purple were used for training, while blue and bluegreen were used as test stimuli. Test trials on which only blue and bluegreen were presented (T(TT) trials which will be described later) consistently occupied half of the non-effective trials which were included in the proportion 24/100. On all other trials, effective or non-effective, only red and purple were presented.

The second-order VR schedule was appropriately introduced. Every correct response on the effective trials increased the VR counter by one. Correct responses which did not satisfy the VR were followed by a short horohoro-buzzer sound of 0.5 s. No feed-back was given to subjects on non-effective trials. A non-correction method was employed. Eighty reinforcements ended each session. This was continued until accuracies of baseline trials with red and purple exceeded 90 % for three successive days.

Test 2 : After reaching the criterion, blue and bluegreen were taken away and the subjects were given preparatory sessions for the following tests. For T320, as the last reinforcement schedule was VR2, 2 sessions were given under the condition of 24/100 (24 non-effective trials per 100 trials) with a VR2 schedule, then, VR was increased to three. For K371, because the last reinforcement schedule was VR3, similar two VR2 sessions were omitted. After three sessions of 24/100 with VR3, both subjects were given six sessions of 48/100 with VR2. Then, the following tests were conducted.

Two new colors — yellow and yellowgreen — were introduced. By combining these new stimuli with baseline stimuli — red and purple —, three types of test trials could be constructed. That is, (a) trials in which samples were baseline stimuli and incorrect comparisons were test stimuli — B(BT) trials —. (b) trials in which samples were test stimuli and incorrect comparisons were baseline stimuli — T(TB) trials —, and (c) trials in which both samples and incorrect comparisons were test stimuli — T(TT) trials. Every 100 trials contained the following trials : 52 effective baseline trials, 28 non-effective baseline trials, 8 non-effective B(BT) trials, 8 non-effective T(TB) trials, and 4 non-effective T(TT) trials. The value of VR was kept at two. Three test sessions were conducted with the limit of 80 reinforcements per session.

Fig.1

Results

The results of the baseline training and test 1 are shown

in Fig.1. The percent of correct responses is in the upper panel, and the percent of right key responses is in the lower panel. Both subjects reached high levels of accuracy in the baseline trials, while strong position preferences kept the accuracies in test trials at almost a chance level throughout the training period.

Fig.2

The results of test 2 are shown in fig.2, in the same way as in fig.1. High accuracies are found in the baseline trials during the test period. Both subjects showed almost 100 % accuracies on B(BT) trials, but nearly 0 % on T(TB) trials on the first day. That is, they kept responding to the baseline stimuli without regard to the sample stimuli. On T(TT) trials, accuracies were at almost a chance level. No transfer was observed. As for K371, these tendencies were not changed in three sessions. But T320 fell into strong position preferences as the sessions repeated, and accuracies came to a chance level on all types of test trials by the third day.

The mean number of reinforcements per minute in the preceding baseline session and in each of the test sessions was as follows: 1.99, 1.94, 1.89, and 2.00 for T320, and 2.71, 2.81, 2.77, and 2.55 for K371.

Discussion

The chance level accuracies of test 1 suggest that the general-relation control does not become strong in any stages of acquisition. It is possible, however, that some accidental responses (position preferences in this case) on test trials became fixed by receiving negative reinforcement,

because no time-out or buzzer sounds were contingent to the response. Accordingly, this kind of transformation of stimulus control cannot be rejected positively. In order to get rid of the effect of the negative reinforcement, the results of later stages should not be stressed. Thus, the non-effective trial method was not appropriate to such long-term tests.

During the sessions of test 2, the rate of reinforcement was kept at almost the same level as the preceding baseline session. Stable responding was obtained in both subjects. Thus, it was confirmed that this non-effective trial procedure was effective to gurantee stable responding in test sessions.

In test trials, the gradual increase of left key preference was shown by T320. The preference seems to be the consequence of the negative reinforcement. Thus, only the first session could be a proper test for this subject. The marked high accuracies on B(BT) trials and near chance accuracies on T(TT) trials, which are observed in both subjects, appear to support the specific-relation control. However, this is still uncertain because the accuracies on T(TB) trials are extremely low. The low accuracies are clearly the results of preference for the baseline stimuli. The same preferences might be responsible for high accuracies on B(BT) trials. These preferences, which were also observed in Jackson & Pegram's (1970a) extradimensional transfer test and in Kojima (1979), seem to occur quite often if unfamiliar test stimuli are presented with familiar baseline stimuli. Accordingly, preferences for the baseline

stimuli must be weakened by some operation in order to decide which of the three types of stimulus control actually functions.

On T(TT) trials, accuracies were consistently at a near chance level, and no transfer was observed. But this result does not wholly support the view that no general-relation control actually works, because performances might be disrupted simply by the presentation of novel stimuli, and, also, because the discriminations necessary for the matching-to-sample task between two test stimuli might not be sufficiently established. Some operation to decrease the novelty of the test stimuli and to establish their functions as discriminative stimuli would be necessary in order to decide whether there is any general-relation control or not. Considering these points, a more pointed design had to be formulated, as presented in the next experiment.

As Carter & Eckerman (1975) pointed out, a matching-to-sample task includes two basic discriminations. One is the successive discrimination between samples, and the other is the simultaneous discrimination between comparison stimuli. Thus, a procedure which familiarizes subjects with test stimuli, to weaken their preference for baseline stimuli, and, simultaneously, establishes these two basic discriminations should be effective. Accordingly, repeated discrimination reversal training was given to the subjects with the test stimuli before entering the matching-to-sample training phase. The appropriateness of the three models of stimulus control ought to be better evaluated using this procedure.

Method

Subjects. The subjects were two three-year-old Japanese monkeys (Macaca fuscata fuscata), T378 (male) and T387 (female). They had been artificially reared since birth, and had chain-pulling experiences, lever-pressing experiences, discrimination in WGTA, and so on. They had not experienced matching-to-sample tasks, nor any problems which incorporated same-different judgments. Their body weights remained at 90-95 % of their free-feeding weights.

Apparatus. The same equipment as in experiment 1 was used.

Procedure. Preliminary training : After shaping responses to a lighted key, response sequences necessary for

discrimination reversal training was initiated. Each trial started with white illumination of the self-start key. Three responses to the key (FR3) turned on either the center key or one of the two side keys, in white. When the center key was turned on (center key trial), the tenth response to the center key was reinforced (FR10). On the other hand, when one of the two side keys was illuminated (side key trial), a response to the lighted side key was reinforced (continuous reinforcement : CRF), but a response to the unlit side key was followed by a 5 s time-out. Events contingent to reinforcement and time-out were exactly the same as in experiment 1. An intertrial interval of 5 s followed reinforcement or time-out periods. Center key trials and side key trials were randomly presented, with the same frequency. Eighty reinforcements ended each session. This continued until the subjects' responses were stabilized.

Repeated discrimination reversal training : The reversal training was conducted with half of the four test stimuli. For T378, blue and bluegreen were used in this training, while yellow and yellowgreen were not used. Conversely, yellow and yellowgreen were used in the training of T387, while blue and bluegreen were not used. Before discrimination training, these two stimuli were presented in place of the white light, in the preliminary training procedure, to habituate the subjects to these colors. Discrimination training started after consistent performances occurred.

In the discrimination training, stimuli were presented in the same temporal sequence as in the preliminary training.

The difference was that the two color stimuli were simultaneously presented in the side key trials. One of the two colors was S+ and the other was S-. A response to S+ was reinforced and a response to S- was followed by a time-out. In the center key trials, the tenth response was reinforced in the presence of S+ (FR trial), but if S- was presented, responses were extinguished, and the stimulus stayed on until subjects paused for 5 s (dro trial). Intertrial interval was 5 s in length and each session ended with 2 h or 80 reinforcements, whichever came first. Each subject received fifteen reversals of S+ and S-. The following response indices were used as the criterion in making reversals: the percentage of correct responses on side key trials, the percentage of FR trials on which no inter-response time was longer than 5 s, and, that of dro trials on which no response occurred. The first three reversals were made at the criterion that all of the three indices were above 90 % for three successive sessions. Later reversals were made at a lower criterion, that the indices were above 85 % for one session. When the subjects did not easily satisfy these criteria, the duration of the intertrial interval and time-out periods were appropriately operated. For the fourteenth reversal of T387, the index of dro trials did not reach to the criterion. But she was thought to have passed the criterion because the number of responses was zero or one for any dro trial.

Matching-to-sample training : After reaching the criterion in the fifteenth reversal, subjects were trained for one session to master the response sequence necessary for

matching-to-sample, with white light, as was done in experiment 1. In the next two sessions, the same training continued with the stimuli which were to be used in the baseline matching-to-sample training (red and purple). On the next day, baseline training started.

Matching-to-sample training was almost the same as experiment 1. But no test stimuli were presented and no non-effective trials were inserted during the training period. Intertrial intervals were again 0.5 s in duration, and each session was ended after 2 h or 80 reinforcements, whichever came first. The second-order VR schedule was appropriately used, and non-correction procedures were used as in experiment 1.

The baseline training continued until subjects reached the criterion such that the accuracies were above 90 % for three successive sessions. Next, the following operations were performed to match both subjects' reinforcement schedules to VR4. As T378 reached the criterion with VR2, the value of VR was increased gradually. But because his performance severely deteriorated with VR3, he was retrained with CRF. Thirteen sessions were necessary to increase the VR value to 4. On the other hand, T387 reached the criterion with VR4. Thus, no additional training was necessary for her.

The following sessions were conducted at VR3 with 24 non-effective trials per 96 trials (10 sessions for T378, 2 sessions for T387). Next, the number of non-effective trials were doubled — that is, 48 non-effective trials per 96 trials — and the value of VR was decreased to 2. The following tests were carried out after the above criterion

was satisfied (4 sessions for T378 and 3 sessions for T387).

Test : Four test stimuli were divided into two groups. One group contained blue and bluegreen, and the other group contained yellow and yellowgreen. Each color of the two groups was combined with the baseline stimuli — red and purple — to make up 20 kinds of test trials for each group. Every test trial included at least one test stimulus. Colors were not combined across two groups. The test trials were presented in the form of non-effective trials.

There were three types of test trials, as in experiment 1. That is, B(BT) trials, T(TB) trials, and T(TT) trials. Each of the three types may be divided into two: whether the test stimuli were used in the previous discrimination reversal training, or, not. To distinguish these two cases, the representations of B(BD), D(DB), D(DD) will be used for test trials with previously trained stimuli. Every 96 trials consisted of the following trials: 48 effective baseline trials, 8 non-effective baseline trials, 8 non-effective B(BT) trials, 8 non-effective T(TB) trials, 4 non-effective T(TT) trials, 8 non-effective B(BD) trials, 8 non-effective D(DB) trials, and 4 non-effective D(DD) trials. Tests were repeated for 3 sessions with VR2.

Results

The number of sessions necessary for fifteen discrimination reversal trainings was 112 for T378, and 163 for T387. The last two reversals needed 4 and 2 sessions for T378, and 5 and 4 for T387 (criterion sessions were excluded).

Baseline matching-to-sample was mastered in 18 sessions for

T378, and 29 sessions for T387. The reinforcement schedule when the subjects reached criterion was VR2 for T378, and VR4 for T387.

Fig.3

The results of the tests are shown in fig.3. Both subjects maintained accurate responding on baseline trials during test periods, except that T387 showed slightly, but not severely, deteriorated accuracy in her first test session. On B(BT) and B(BD) trials, in which samples were the baseline stimuli, high accuracies were shown — all of which were significantly above chance, $p<.01$. But accuracies were almost at chance level on T(TT) trials, in which only unfamiliar test stimuli were presented. In the first and the second sessions, intermediate levels of accuracy were seen on D(DD) trials, in which only the stimuli which had been used in the previous discrimination reversal training were presented — significantly above chance at a 5 % level in the second session for T387, but the remainder not significant because of the small sample size. These observations were consistent for both subjects.

For T387, accuracies were extremely low on T(TB) and D(DB) trials, for which samples were test stimuli. On the other hand, accuracies were at almost chance level for T378 on both T(TB) and D(DB) trials in the first session, but dropped to a low level in the second session. In the third session, significantly above chance accuracy ($p<.01$) was shown on D(DB) trials, but on T(TB) trials accuracy was as low as that in the second session.

The position preferences were not extreme for most kinds of test trials except on the T(TT) trials of the second and the

third sessions of T378. The mean number of reinforcements per minute in the preceding baseline session and the test sessions was as the following: 1.45, 1.39, 1.44, and 1.65 for T378, and 1.42, 0.89, 0.58, and 1.18 for T387.

Discussion

The slight deterioration of performance shown by T387, which gave rise to a decrease in rate of reinforcement, seems to have been caused by the simple presentation of test stimuli. It is, however, one of inevitable problems in conducting tests with new stimuli. On the other hand, T378 performed consistently throughout the test period.

With regard to the stimuli which had not been used in the discrimination reversal training (yellow and yellowgreen for T378, blue and bluegreen for T387), accuracies were high on B(BT) trials and very low on T(TB) trials, which suggests a strong preference for baseline stimuli. The first session of T378 was an exception. On T(TT) trials accuracies were at almost chance level. These results were consistent with those of experiment 1.

There are two aspects worth noting for the effects of the discrimination reversal training. One aspect is the strengthening of the tendency of the subjects to choose test stimuli used in the previous discrimination reversal training. As a result of repeated reversal training, two test stimuli seemed to have acquired the same amount of strength. These effects will be evident by comparing the results of B(BD) and D(DB) trials with those of B(BT) and T(TB) trials. The other aspect is the formation of

discrimination between two test stimuli. From the result of the discrimination reversal training, it is clear that with regard to the two test stimuli (blue and bluegreen for T378, yellow and yellowgreen for T387) both the successive discrimination when the stimuli were presented as sample stimuli and the simultaneous discrimination when presented as comparison stimuli were established. Comparison of the results of D(DD) trials with those of T(TT) trials will reveal these effects.

The first aspect may be explored further. When the sample was one of the baseline stimuli (red and purple), the accuracies on B(BD) trials with test stimuli used in the previous discrimination reversal training were comparable to those of B(BT) trials. High accuracies were shown in both cases. Similarly on the trials in which the sample was one of the test stimuli (T(TB) trials and D(DB) trials), no differences were shown except that the accuracy was high on D(DB) trials on the third day for T378. This peculiarly high accuracy was the result of consistent right key preference on two kinds of trials with specific configurations of stimuli, which was, incidentally, the correct response, and of almost consistent left key preference on the other kinds of trials. The negative reinforcement described earlier might have played some role in fixing this preference. Thus, it is dangerous to interpret this peculiarly high accuracy as a product of the general-relation control. It would be more prudent to consider that no differences were observed between T(TB) trials and D(DB) trials. Unfortunately, this aspect of the

discrimination reversal training did not have sufficient effect to rival the strong tendency of the baseline stimuli to make the subjects press the keys.

With regard to the second aspect, the effects of the prior establishment of the discriminations were shown in D(DD) trials in comparison with T(TT) trials. On T(TT) trials, accuracies were at approximately a chance level. On D(DD) trials, however, about 60-70 % accuracies were shown in the initial two days. With regard to the initial two sessions, the difference between the two types of trials was significant ($F=11.87$ $df=1,4$ $p<.05$). These differences suggest that the identity between sample stimuli and comparison stimuli controlled the subjects' responding during the baseline matching-to-sample training, and prior establishment of two basic discriminations included in matching-to-sample tasks made it possible to detect the general-relation control. But the control was not observed on the third day, probably an effect of the negative reinforcement described earlier.

Among the three stimulus control models, the configuration control model cannot explain the high accuracies for the several types of test trials which had new configurations of stimuli. With regard to the specific-relation control, it is still not possible to decide clearly whether the control actually functioned or not, because the first aspect of the discrimination reversal training was not sufficiently effective. But it is quite important that the existence of the general-relation control was demonstrated without any confusing factor. Successful transfer to new stimuli was

demonstrated previously by Jackson & Pegram (1970a) and Mello (1971). But, because these workers maintained differential reinforcement in tests, the successful transfer shown by their monkeys might be due, at least partly, to very rapid savings.[2] In this experiment, there is no room for savings to occur. Thus, although only weak transfer was observed, the transfer was strong evidence that the general-relation of sample and comparison stimuli actually controlled, at least in part, two-color matching-to-sample behaviors of Japanese monkeys.

Stimulus control in two-color matching-to-sample behaviors of Japanese monkeys was analyzed with the use of non-effective trials in which no feed back was given to subjects regardless of their responding. Though this procedure introduces questions regarding the effects of negative reinforcement, the results can be safely evaluated because such negative reinforcement has no tendency to affect the accuracies one-directionally, as is the case with differential reinforcement employed in previous works. Furthermore, as the rate of reinforcement is not affected by the accuracies of test trials, emotional responding which results from a decrease in the rate of reinforcement will not occur. Thus, this non-effective trial procedure is also effective to gurantee stable responding during test sessions, which was confirmed in experiment 1. The effects of such learning factor produced by differential reinforcement and those of decrease in the rate of reinforcement in test sessions have been given little attention in previous studies. In order to examine stimulus control of the complex discriminated operants more precisely, it is necessary to adopt procedures which provide no differential reinforcement and, also, keep the rate of reinforcement from decreasing, as was done in the present experiments.

In the second experiment, evidence that the general-relation of sample and comparison stimuli actually controlled matching-to-sample behaviors was obtained in Japanese monkeys, despite the fact that only two color

stimuli were used in the training. The general-relation control has not been demonstrated in pigeons with standard matching-to-sample task. For instance, Farthing & Opuda (1974) trained pigeons, beforehand, to peck at test stimuli which were presented alone, but transfer to the stimuli was not clearly observed. Similarly, the general-relation control was not substantiated by Carter & Taten (1977), who used a learning set procedure, or, Holmes (1979), who conducted a number of repeated transfer testings. These data on pigeons suggest that, as Carter & Werner (1978) concluded, the general-relation control does not appear to be strong in pigeons' usual matching-to-sample behaviors, even in those cases where fairly numerous stimuli are used for training.[3] But, until transfer performances are examined for stimuli for which the two basic discriminations included in matching-to-sample tasks are sufficiently established, it cannot be presumed that the general-relation does not control pigeons' matching-to-sample behaviors whatsoever, nor that species differences in their abilities between pigeons and monkeys are critical.

The general-relation control detected here, however, appeared to be extremely weak, even though transfer performances were examined to test stimuli for which the two basic discriminations between the stimuli were completely established. Two interpretations of this apparent weakness are possible. One is that the general-relation control actually is not weak, but the baseline stimuli themselves play a major part as the conditional discriminative stimuli on which the general-relation control works. If this is the

case, the general-relation has difficulty exerting its control in the test trials, especially where the samples are not baseline stimuli. The other is the possibility that both the specific-relation and the general-relation simultaneously control subjects' responding, the former being relatively stronger. It is not possible to decide which of these two interpretations is correct from the present experiment. In order to decide which is the case, transfer should be examined in a situation where another clear conditional discriminative stimulus is established in addition to the baseline stimuli both in the training and in the tests.

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Footnotes

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2. The number of stimuli used for training before tests were conducted should also be considered. Jackson & Pegram (1970a) used three colors for baseline, and Mello (1971) trained subjects to match several new stimuli before testing. Thus, successful transfer to new stimuli seems to have occurred more easily in their works than in the present experiments.

3. The general-relation control, however, is thought to work in some modified procedures other than standard matching-to-sample. Refer to Honig (1965), Malott & Malott (1970), Zentall & Hogan (1975), Urcuioli & Nevin (1975), Urcuioli (1977), and Zentall & Hogan (1978).

Figure Captions

Fig.1. The accuracies (upper panel) and the percent of the right key choice (lower panel) of the baseline and the test trials during the acquisition of the 0-delay color matching-to-sample.

Fig.2. The results of test 2 of experiment 1. The accuracies of each types of trials (see text) are shown in the upper panel, and the percent of the right key choice is shown in the lower panel.

Fig.3. The results experiment 2. The accuracies of each type of trial (see text) are shown in the upper panel, and the percent of the right key choice is shown in the lower panel. The open symbols designate test trials in which familiar test stimuli, used in the previous discrimination reversal training, were presented, while the filled symbols, other than circle (baseline trials), designate test trials in which unfamiliar test stimuli were presented.

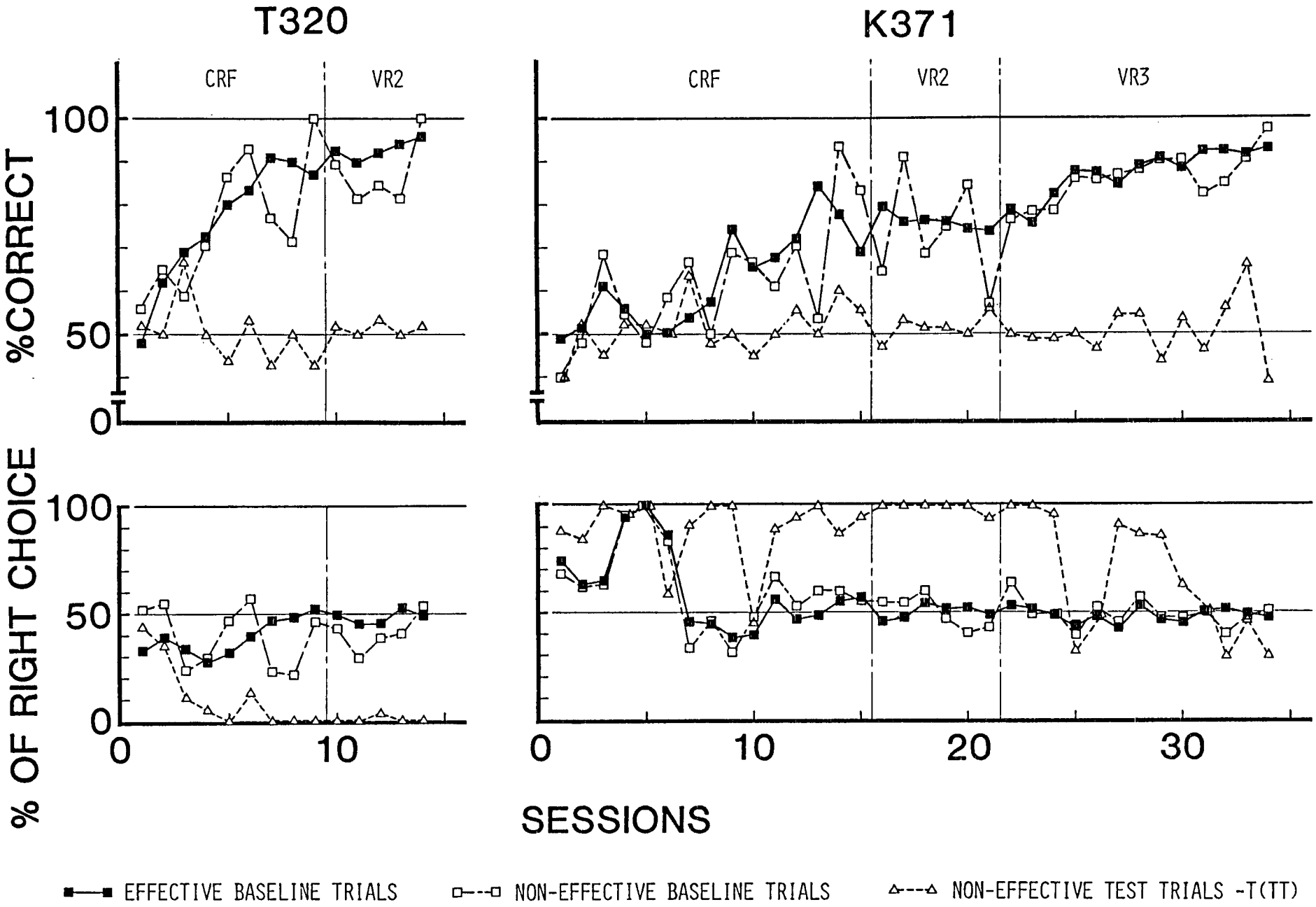
T320
K371
CRF
VR2
VR3
100
50
0
%CORRECT
% OF RIGHT CHOICE
0
10
20
30
SESSIONS
EFFECTIVE BASELINE TRIALS
NON-EFFECTIVE BASELINE TRIALS
NON-EFFECTIVE TEST TRIALS -T(TT)

Fig 1

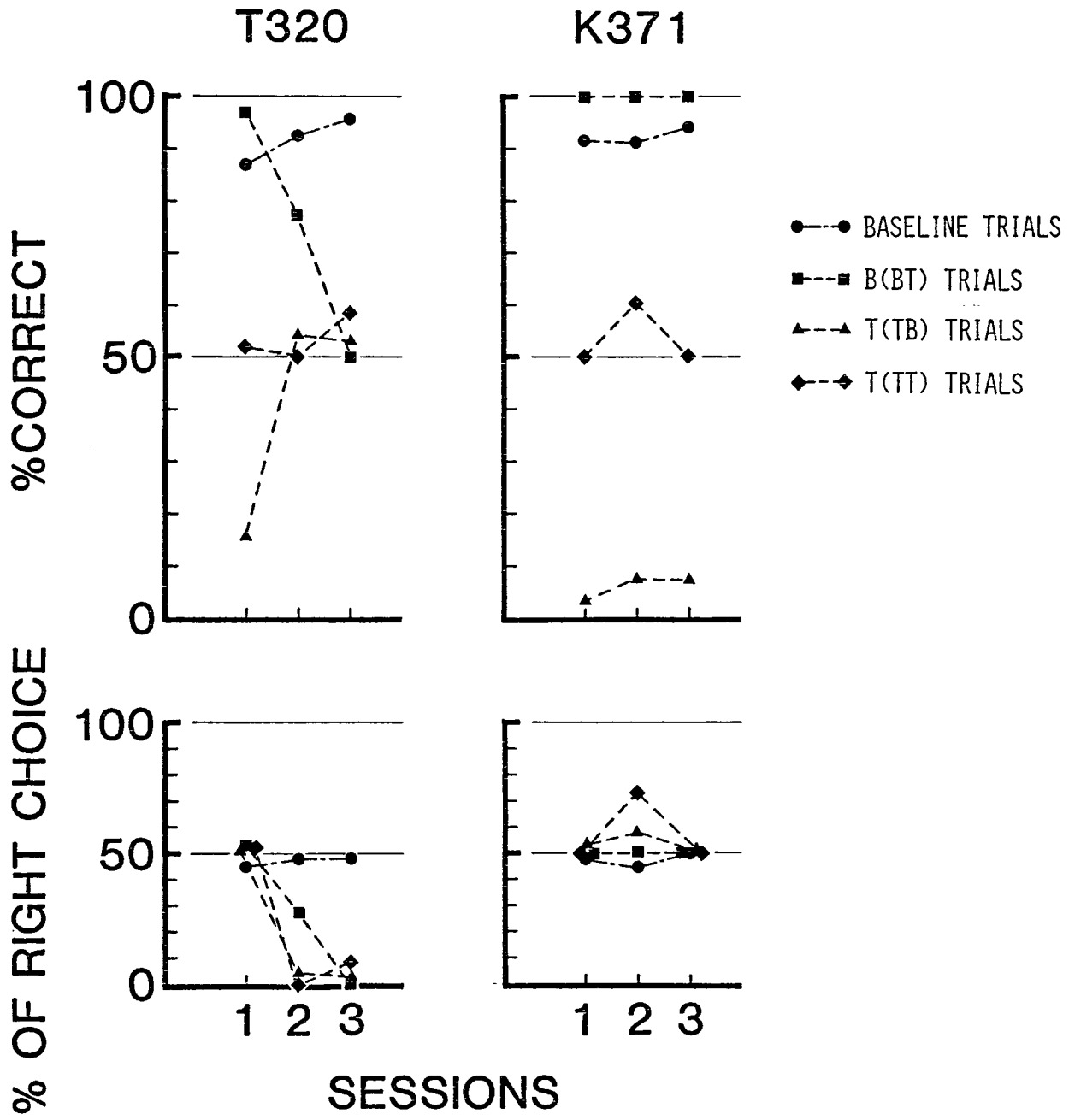
T320
K371
100
50
0
%CORRECT
100
50
0
% OF RIGHT CHOICE
1 2 3
1 2 3
SESSIONS
BASELINE TRIALS
B(BT) TRIALS
T(TB) TRIALS
T(TT) TRIALS

Fig. 2

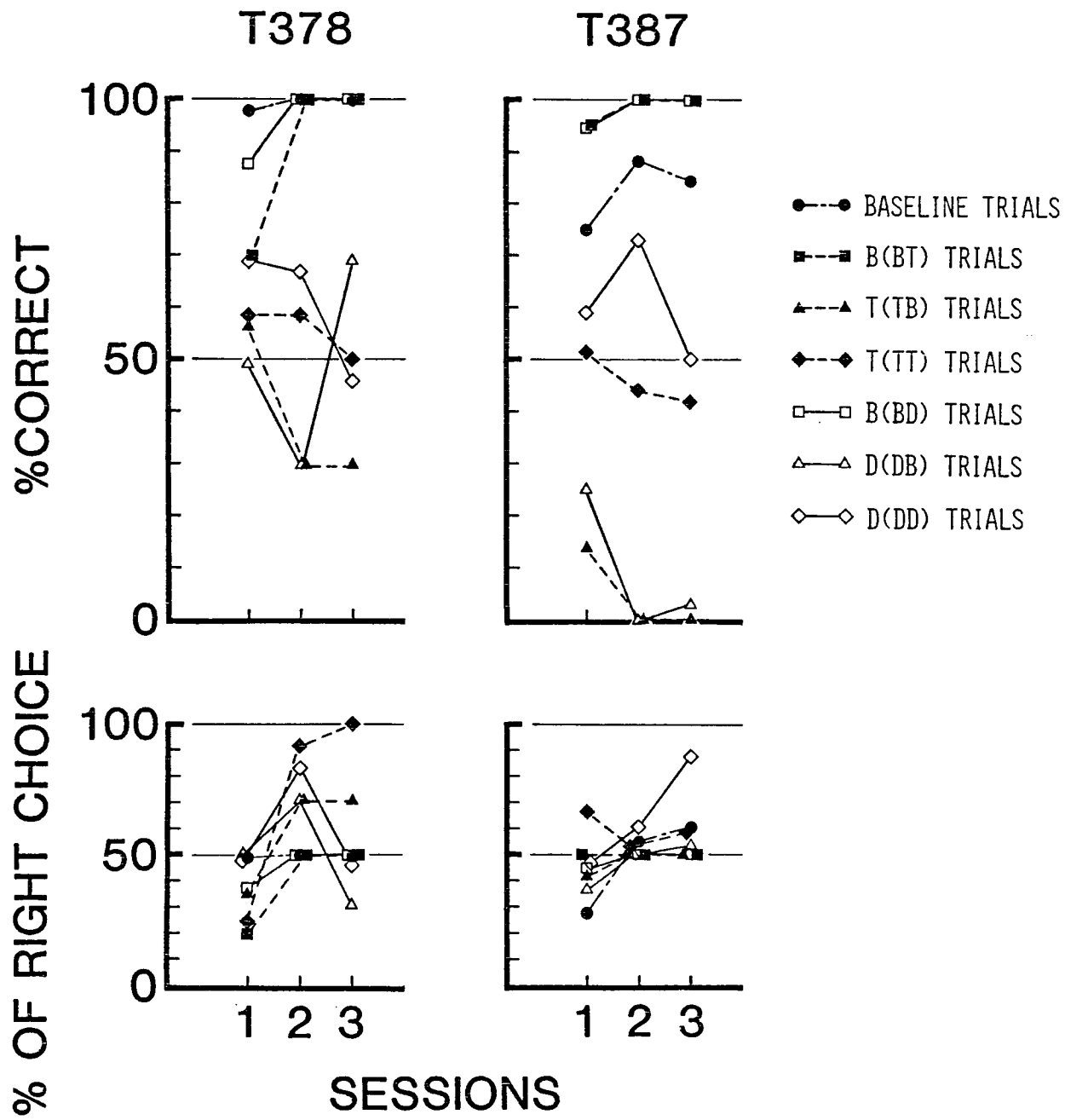
T378
T387
100
50
0
%CORRECT
% OF RIGHT CHOICE
1 2 3
SESSIONS
BASELINE TRIALS
B(BT) TRIALS
T(TB) TRIALS
T(TT) TRIALS
B(BD) TRIALS
D(DB) TRIALS
D(DD) TRIALS

Fig. 3

Acquisition and transfer of a higher-order conditional discrimination performance in the Japanese monkey.

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Abstract

Acquisition and transfer of a higher-order conditional discrimination performance in the Japanese monkey.

Stimulus control of matching-to-sample behaviors of Japanese monkeys was investigated by analyzing transfer performances of a higher-order conditional discrimination consisting of a matching-to-sample and an oddity-from-sample behavior with two colors. Patterns on the self-start key and the number of required responses to complete a trial were different between these two tasks. As these conditional discriminative stimuli were kept present even on test trials where no baseline stimulus appeared, it was supposed that, if the identity of sample and comparison stimuli controlled Ss' behaviors relatively strongly, such general relation between the stimuli could easily exert its control in test trials, compared with simple matching-to-sample tasks. Both two monkeys acquired this complex discrimination. Then, the stimulus control was tested in non-effective trials. Ss performed well on trials lacking incorrect comparison stimulus, but poorly on transfer trials where only new colors appeared. It was concluded that the control by the general relation between stimuli was extremely weak, and that the specific relation between the sample and the correct comparison stimulus mainly controlled both their matching-to-sample and oddity-from-sample behaviors.

Key words : monkeys, operant conditioning, key press,

stimulus control, concept formation, conditional discrimination, matching-to-sample, oddity-from-sample.

Fujita (in preparation) analyzed the stimulus control in two-color matching-to-sample behaviors of Japanese monkeys by examining transfer performances to new colors, using "non-effective" trials in which no differential reinforcement was made. Although no transfer to unfamiliar test stimuli resulted, weak transfer was observed to familiar test stimuli for which the successsive discrimination and the simultaneous discrimination between the stimuli were priorily established. He concluded that the general relation of "identity" between the sample and the comparison stimulus controlled, at least in part, two-color matching-to-sample behaviors of Japanese monkeys. (In other words, subjects acquired, although only incompletely, the general rule to choose the same comparison stimulus as the sample.)

As he suggested, two interpretations of the apparent weakness of such relational control (which was labelled as the "general-relation control") are possible. One is that although the general-relation control is not weak, baseline stimuli themselves play a major part as the conditional discriminative stimuli on which the general-relation control works. In this case, the accuracies on test trials where no baseline stimuli are presented should decrease because the general-relation has difficulty exerting its control in the absence of the baseline stimuli. The other is that both the control by the specific relation between the sample and the comparison stimuli (the "specific-relation control") and control by the general-relation between the stimuli work at the same time, and the former is relatively stronger. (The specific-relation control can be described, in other words,

as follows: subjects acquire a set of sample-specific rules as, for example, to choose red if the sample is red.)

In order to decide which of these two interpretations is correct, transfer performances must be tested on the situation where some stimuli other than the baseline stimuli are controlling the subjects' behaviors as a conditional discriminative stimulus. A higher-order conditional discrimination task which includes both matching-to-sample and oddity-from-sample should be appropriate as such a situation, to examine how strong the general-relation control actually is. If the transfer to new stimuli occurs in this situation, the first interpretation is supported, and if no transfer is observed, the second is supported. Seen in more detail, when the second interpretation is supported, two specific-relations between stimuli have the potential to control the subjects' behaviors. One is the specific-relation between the sample and the correct comparison stimulus, and the other is that between the sample and the incorrect comparison stimulus. These two possibilities can be checked by testing the subjects' performances on trials where only one of the two comparison stimuli is presented.

The purpose of the present experiment is (a) to establish this higher-order conditional discrimination which consists of matching-to-sample and oddity-from-sample in Japanese monkeys, and (b) to examine the stimulus control in their two-color matching-to-sample behaviors, utilyzing this situation.

Subjects

The subjects were two five-year-old male Japanese monkeys (Macaca fuscata fuscata), T320 and K371. Both subjects had acquired a 0-delay matching-to-sample performance with two colors — red and purple — in the preceding experiment. Body weights of the subjects remained at 90-95 % of their free-feeding weights throughout the experiment.

Apparatus

The same equipment as in Fujita (in preparation) was used. The experimental chamber (70 cm X 70 cm X 70 cm) was located in a dark room filled with masking white noise. The experimental panel was attached to one side-wall of the chamber. A small translucent window (20 mm X 70 mm) at the top of the panel was used as a room light by illuminating with a 24 V tungsten lamp. Three transparent acrylized keys (50 mm X 35 mm) were installed in the center of the panel, each key separated by 60 mm, center to center. A small self-start key (25 mm X 35 mm) was placed 85 mm above the top of the center key. I. E. E. in-line projectors were attached behind these four keys. Soybeans, which were used as a reinforcer, were presented in the feeder tray at the bottom of the panel, by a pellet dispenser. The tray was illuminated by a 24 V tungsten lamp. A minicomputer (DEC PDP8/F) controlled the equipment. Data were collected by the minicomputer and a cumulative recorder (Ralph Gerbrands). Subjects' performances were monitored with a TV camera.

Procedure

Acquisition phase. Both subjects had already performed accurately on a 0-delay matching-to-sample task with red and purple. In this matching-to-sample trial, the self-start key was lighted white first. Three responses to the key (fixed-ratio 3 : FR3) turned on the center key to red or purple (sample stimulus), with the self-start key remained lit. Ten responses to the center key (FR10) turned off the sample stimulus, and, at the same time, two side keys were simultaneously lighted red or purple. A response to the side key which had a color matching the sample was a correct response, and a response to another side key was an incorrect response. All the stimuli on the keys were turned off by the response to either of the two side keys. Correct responses were followed by the presentation of a soybean, accompanied by 1 s Horohoro-buzzer (National Electric) sound and 2 s illumination of the feeder tray. Incorrect responses were followed by another buzzer sound of 1 s and 5 s time-out. The room light was turned off during time-out periods. The next trial started after .5 s intertrial interval which followed the reinforcement cycles or the time-out periods. Any response to the keys during the intertrial intervals or time-out periods reset the clock. The matching-to-sample sessions included "non-effective" trials (see Fujita, in preparation) with the proportion 1/4. In the non-effective trials, no differential reinforcement was made regardless of the subject's response. Intertrial intervals immediately followed the response. A second-order

variable-ratio (VR) schedule was also in effect. A soybean was presented after a few correct responses were made in the "effective" trials. The value of the VR was three in the matching-to-sample sessions. Correct responses in the effective trials which did not satisfy the VR value were followed by a short Horohoro-buzzer sound of .5 s. Responses in the non-effective trials had nothing to do with the VR counter.

The oddity-from-sample trials were initially introduced as a non-effective trial. In the oddity-from-sample trials, black (2 mm wide) and white (3 mm wide) vertical stripes were presented on the self-start key, and nine responses were required to the key (FR9). After the subjects were habituated to the stripes and the differed number of responses to the self-start key, all the trials were made "effective", and the VR value was decreased to 1 (CRF). Although the same color stimuli as the matching-to-sample trials were presented, a response to the nonmatching side key was a correct response.

Matching-to-sample trials and oddity-from-sample trials were alternatively presented as a block (multiple schedule). Eighty reinforcements ended each session. A black-out periods of 5 s was inserted between blocks. The size of the oddity-from-sample block was gradually increased. In the seventh session and afterwards, matching-to-sample block continued from the start of the session until 20 reinforcements were made. The next 40 reinforcements were made in the oddity-from-sample block and the last 20 reinforcements again in the matching-to-sample block. At

the eighth session, the fixed-ratio requirement to the sample was changed from 10 to 3 in the oddity-from-sample trials. The differences between matching-to-sample trials and the oddity-from-sample trials were as follows : the stimulus on the self-start key — white light versus stripes —, the fixed-ratio requirement to the self-start key — 3 versus 9 —, and the fixed-ratio requirement to the sample — 10 versus 3.

The training was continued with a non-correction procedure.[2] The second-order VR schedules were appropriately introduced, as in the preceding matching-to-sample sessions. This was continued until the accuracies of both matching-to-sample and oddity-from-sample trials exceeded 90 % for two successive sessions.

Test phase. After reaching the criterion, the value of the VR was equalized to 6 for either subject. Then, non-effective trials were gradually introduced, and at the same time VR value was lowered to keep the rate of reinforcement unchanged. Lastly, the half of the trials were non-effective, and VR value was 3. The following tests were conducted after the above criterion was again satisfied.

Three kinds of test trials were constructed for either type of tasks. The first was the transfer trial : only two new colors — yellow and yellowgreen — were presented. The second was the S+ trial : the incorrect comparison stimulus in the baseline trial was substituted for the white light, while the correct comparison stimulus was presented. That is, the matching comparison stimulus was presented for matching-to-sample trials, but the white light appeared in

place of the nonmatching comparison stimulus. Conversely, for oddity-from-sample trials, the nonmatching comparison stimulus was presented, while the white light substituted for the matching comparison stimulus. Choosing the non-white comparison stimulus was regarded as a "correct" response. The third was the S- trial : the correct comparison stimulus in the baseline trial was replaced by the white light, while the incorrect comparison stimulus was presented, just opposite to the S+ trial. Choosing the white light was regarded as a "correct" response.

The stimulus control established in the baseline training will be reflected in the accuracies of these test trials. If the general-relation control has been strongly established, subjects will perform accurately on the transfer trials. If the general-relation control is only weakly established and the relatively strong specific-relation control is formed, two cases are possible. When the specific-relation of the sample and the correct comparison stimulus is controlling — in other words, when the subjects have acquired the rules as to "choose ..., if the sample is ..." —, performance on the S+ trials will be accurate. On the other hand, when the specific-relation between the sample and the incorrect comparison stimulus is controlling — or, when they have acquired the rules as to "avoid ..., if the sample is ..." —, accurate performance will be observed on the S- trials.

Each of these three kinds of test trials occupied a quarter of the non-effective trials, and the remainders were non-effective baseline trials. Tests were conducted for

three sessions.

Results

Fig.1

Acquisition phase

Both subjects mastered the higher-order conditional discrimination task. T320 required 39 sessions and K371 needed 77 sessions before reaching the criterion. The last VR value of the baseline was 3 for T320 and 5 for K371. The cumulative records in the last session of the acquisition phase were shown in fig.1. Event records designate incorrect responses. Each trial advanced the stepper by one. The presentation of a soybean was marked as a pip on the cumulative record. Both subjects showed quite consistent performances as long as the task was kept unchanged, and quickly switched their responding as soon as the task was alternated.

Fig.2

Test phase

The results of the tests were shown in fig.2. The upper column shows the percent of correct responses, while the lower column shows the percent of responses to the right key. Open symbols denote matching-to-sample, and filled symbols denote oddity-from-sample. No severe deterioration was seen in their baseline trials (circles). Both subjects kept responding with the accuracies above 80 % throughout the test periods.

On the transfer trials (diamonds), in which only unfamiliar stimuli were presented, subjects' performances were severely dropped to a chance level, both in matching-to-sample and oddity-from-sample trials. Their position preferences were

quite extreme. No transfer was observed.

Next, on the S+ trials (squares), in which only the correct comparison stimulus was presented, T320 showed relatively good performances in both types of tasks. K371 performed poorly in his first session, but showed very high accuracies in his second and third sessions for either task, which suggested the development of strong tendencies to avoid white light in the second and the third sessions.

The results of the S- trials (triangles), in which only the incorrect comparison stimulus was presented, were a little complex. T320 showed relatively high accuracies for matching-to-sample, but the acuurcies were almost at a chance level for oddity-from-sample. K371 performed with relatively high accuracies for both tasks in his first session, which implies the tendency to choose the white light in this session, but, conversely, his performance dropped in the second and the third sessions. The accuracies came to be near 0 % especially for oddity-from-sample, which again suggested the development of the strong tendency to avoid white light in these two sessions. However, despite such a strong white-avoiding tendency, accuracies were maintained at a chance level for matching-to-sample.

Discussion

Spaet & Harlow (1943) and Harlow & Moon (1956) trained their rhesus monkeys in the WGTA to choose an odd object on one color of the tray and to choose a nonodd object on another color of the tray. They demonstrated that rhesus monkeys are able to master this higher-order conditional discrimination task named "oddity-nonoddity" problem. The present results of the acquisition phase revealed that Japanese monkeys are also able to acquire a higher-order conditional discrimination, as shown in fig.1. The subjects' performances quickly switched as soon as the tasks were alternated. It is clear that some of the situational differences between matching-to-sample trials and oddity-from-sample trials came to control their complex behaviors as a conditional discriminative stimulus. Previously, complex discriminated behaviors in animals were mostly studied in a discrete-trial situation like the WGTA. In the present experiment, a complex discrimination was analyzed with a free-operant technique. A significant advantage of this procedural alteration is that many experimental variables can be operated quite independently. In the case of this experiment, the procedure made it possible to conduct a strict test of the subjects' performances with no differential reinforcement by introducing a second-order reinforcement schedule.

During test sessions, no transfer to new stimuli was observed. Fujita (in preparation) suggested a possibility that baseline stimuli themselves play a major part as

conditional discriminative stimuli for the general-relation control to work. If that is the case, the general-relation control has difficulty exerting its function in test trials where the essential conditional discriminative stimuli are not presented. However, after the present higher-order conditional discrimination was acquired, it is clear that the controlling function of the general-relation came to be controlled by the higher-order conditional discriminative stimuli other than the baseline stimuli — stripes on the self-start key, FR value on the key, and so on. These higher-order stimuli were kept present even on test trials. Thus, if the general-relation control was relatively strong, the control was predicted to work in test trials. The present results, however, show no transfer. Accordingly, it is concluded that the control by the general-relation between stimuli is extremely weak both in two-color matching-to-sample behaviors and in oddity-from-sample behaviors of Japanese monkeys, and that their behaviors are principally controlled by the specific-relation between the sample and the comparison stimuli.

As described earlier, two kinds of specific-relations have the potential to control their behaviors. The first is the specific-relation between the sample and the correct comparison stimulus, and the second is that between the sample and the incorrect comparison stimulus. Which of the two kinds of stimulus control was working can be distinctively decided from the results of the tests shown by T320 (fig.2, left). The high accuracies shown in the S+ trials of matching-to-sample and oddity-from-sample suggest

that the control by the first specific-relation was working in both types of tasks. On the other hand, though the subject also performed well on the S- trials of matching-to-sample, he performed only poorly on the S- trials of oddity-from-sample. That is, the second specific-relation was also controlling his matching-to-sample behavior, but not oddity-from-sample behavior.

For K371, the inconsistency of his performences between sessions makes it a little difficult to interpret the results of the tests. His performance is, as pointed out in the "Results" section, considerably affected by the degree of preference for the white light which changed between sessions. In his first test session, relatively strong preference for the white light advantaged the accuracies on the S- trials, but lowered the accuracies on the S+ trials. Conversely, in the second and the third session, as the preference was reversed to avoid the white light, the accuracies on the S+ trials was advantaged, while the accuracies on the S- trials were disadvantaged by the tendency. Considering the degree of the preference, the similar interpretation as was made for T320 is possible — that is, relatively high accuracies on the S+ trials for both types of tasks and on the S- trials of matching-to-sample, but low accuracies on the S- trials of oddity-from-sample. Thus, it is suggested that both the first and the second specific-relations were also controlling matching-to-sample behavior of this subject, but only the first one was controlling his oddity-from-sample behavior.

The fact that the relation between the sample and the

matching comparison stimulus did not control oddity-from-sample behaviors is somewhat surprising. But the similar phenomenon was also seen in pigeons (see Carter & Werner, 1978). Thus, it can be said that animals do not easily solve oddity-from-sample tasks with the strategy avoiding the matching comparison stimulus, which seems to be natural for us humans. Another surprising finding is that specific-relation between the sample and the nonmatching — that is, incorrect — comparison stimulus as well as that between the sample and the matching comparison stimulus controlled the matching-to-sample behaviors. This is inconsistent with Carter & Werner's (1978) conclusion in pigeons that only the latter one is working. It is not easy to decide whether this inconsistent finding is based on the differences between species or consequenced from the effect of the multiple scheduling with the oddity-from-sample task. But, from the present result that such a control by the negative stimulus was not observed in oddity-from-sample behaviors, it is supposed that the effect of the multiple schedule is critical.

All the findings obtained in Fujita (in preparation) and in the present study being considered, the following conclusions are reasonable. Two-color matching-to-sample behaviors of Japanese monkeys are weakly controlled by the general-relation between the sample and the comparison stimuli, but mainly controlled by the specific-relation between the sample and the correct comparison stimulus. Their oddity-from-sample behaviors are also controlled by this specific-relation.

The present experiment clarified that the general-relation control was extremely weak in matching-to-sample behaviors when the limited number of stimuli were used. The fact is a little surprising because relatively strong general-relation control was suggested in pigeons when some modified procedures similar to matching-to-sample were employed (Honig, 1965; Malott & Malott, 1970; Urcuioli & Nevin, 1975; Zentall & Hogan, 1978; etc.). Carter & Werner (1978) criticized most of these works by pointing out some procedural defects. However, considering the fact that no reports in pigeons which employed standard matching-to-sample procedure succeeded to demonstrate strong general-relation control, some experimental variables other than the number of stimuli are supposed to play an important role for changing the strength of this control. Thus, it should be studied further what independent variables have the critical effect to establish relatively strong general-relation control.

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Footnotes

1. The author is deeply indebted to professor Kiyoko Murofushi, Ph.D., for her kind and useful advices in preparing the manuscript.

2. A correction procedure was employed in the oddity-from-sample block for two sessions of K371, in order to remove his strong position preference.

Figure captions

Fig. 1. The cumulative record of the individual performance in the last session of the acquisition phase. The event records denote incorrect responses. A trial advanced the stepper by one. Second-order VR schedules being employed, only the presentation of a soybean was marked as a pip on the cumulative record. MTS is the abbreviation of the matching-to-sample and OFS the oddity-from-sample. Note that the subjects' performances quickly changed as soon as the task was alternated.

Fig. 2. The results of the tests. The upper column shows the percent of correct responses, while the lower column shows the percent of right key choices. Open symbols designate matching-to-sample, and filled symbols designate oddity-from-sample. No transfer to new stimuli (diamonds) was observed in either type of tasks. See text for detail explanation.

The last session of the acquisition phase.

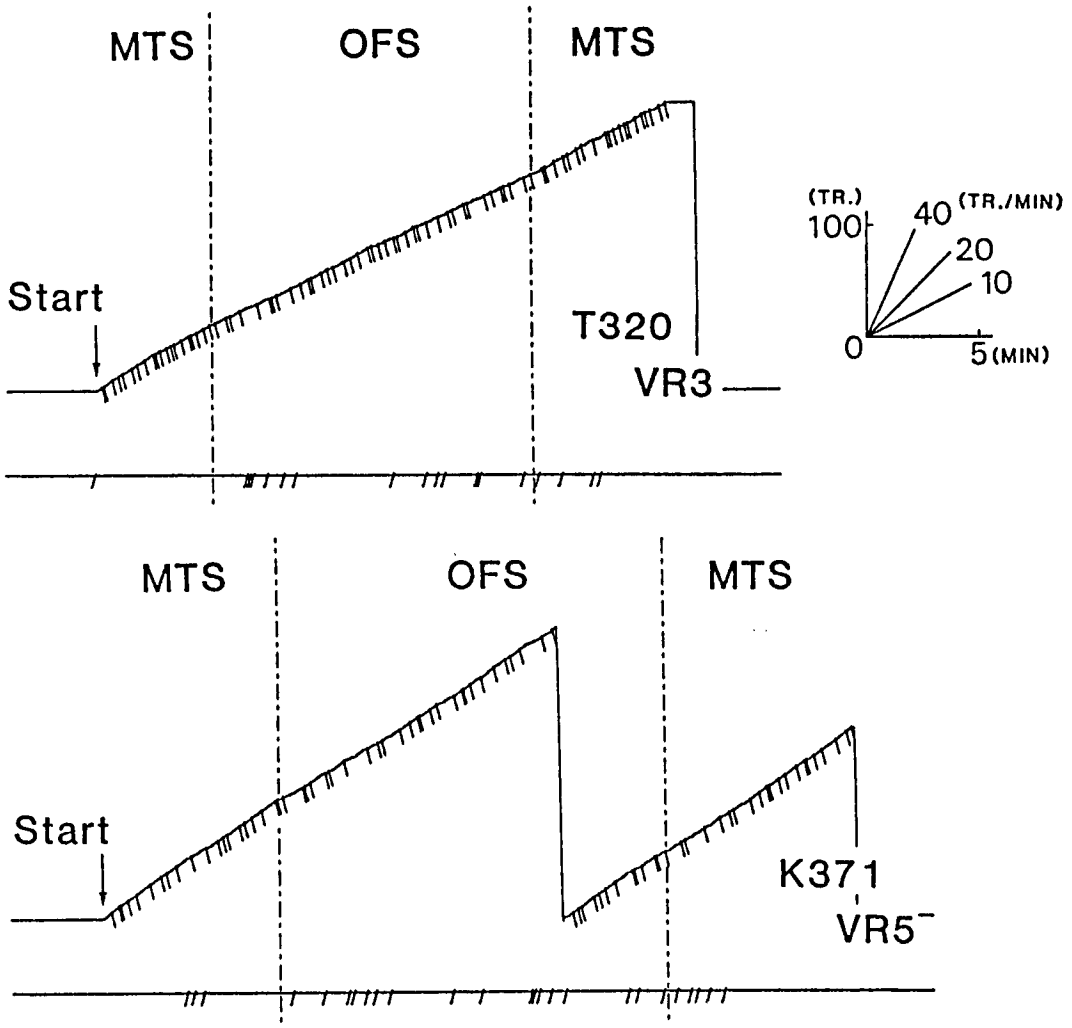
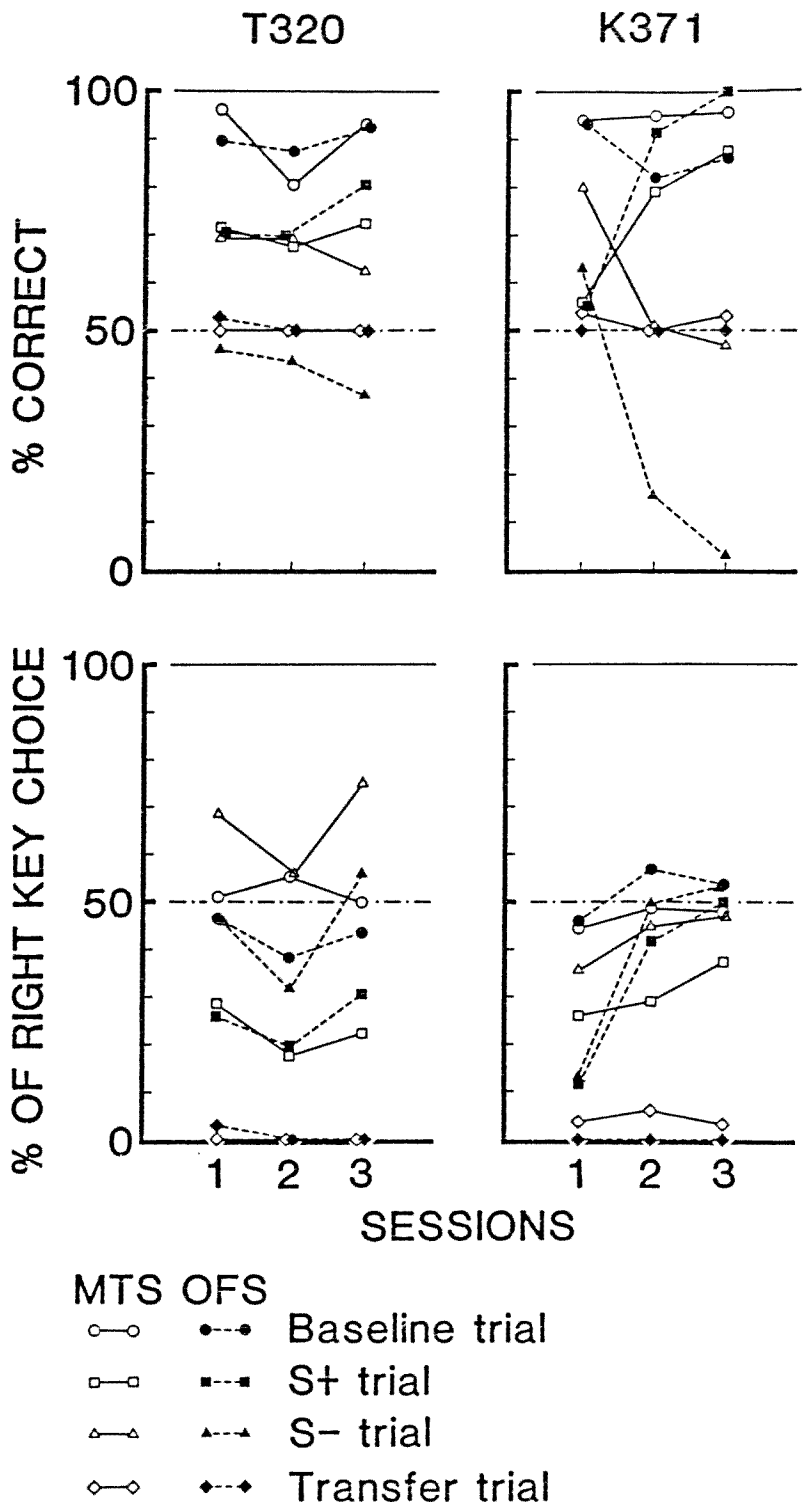


Fig. 1


T320
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% CORRECT
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1 2 3
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SESSIONS
MTS OFS
Baseline trial
S+ trial
S- trial
Transfer trial

Fig. 2